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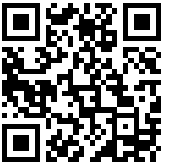

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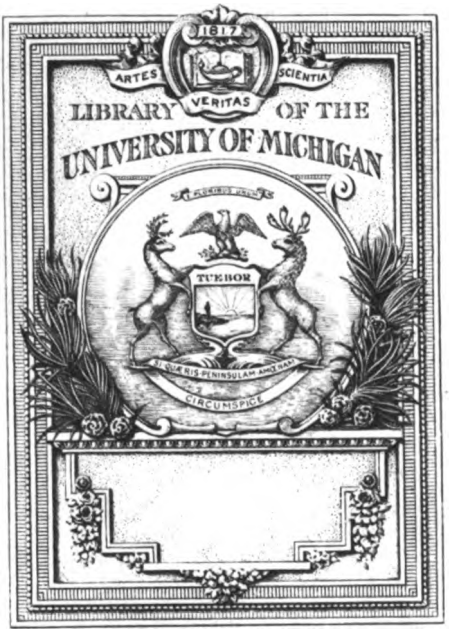

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MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

1916.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HIS MAJESTY'S TREASURY.

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230. AMMANFORD	1 6	1 6	2 6
231. MERTHYR TYDFIL ...	1 6	1 6	1 6
232. ABERGAVENNY	1 6	1 6	2 0
246. WEST GOWER	1 6	1 6	0 8
247. SWANSEA	1 6	1 6	2 6
248. PONTYPRIDD	1 6	1 6	1 6
249. NEWPORT Mon.)... ...	1 6	1 6	1 6
254. HENLEY-ON-THAMES ...	—	1 6	2 0
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334. NEWHAVEN and EASTBOURNE	—	1 6	0 6
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336. CAMELFORD	—	1 6	
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SUMMARY OF PROGRESS

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GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1916.

I.—*INTRODUCTION.*

By A. Strahan, Sc.D., LL.D., F.R.S., Director.

The continuance of the War and an increase in the number of special investigations which are required in connection with it and with industrial policy after it is over, have necessitated a temporary suspension in all districts of the normal work upon which the Survey has been engaged of late years. Already, in 1915, enquiries respecting British resources of a number of minerals of economic value had absorbed much of the time of the staff. As a result, and partly also through an increasing difficulty in engraving and colour-printing maps, it became clear in 1916 that the Survey could best serve the interests of the country by concentrating attention upon such matters, and temporarily suspending all normal field-surveying. Thus the discontinuance of field-work in the London and South-Eastern district in 1915 was followed by discontinuance in the districts of Denbighshire, Shropshire, Staffordshire and Warwickshire, in 1916. In the year 1915 publication of a series of 'Special Reports on the Mineral Resources of Great Britain' was commenced. Similarly, in Scotland, the energies of the staff were directed to continuing the revision of coalfields in preference to carrying on the primary six-inch survey in the Highlands, and eventually, as regards field-work, to dealing with various enquiries arising out of the War, to the collecting of information for the 'Special Reports' and to the examination of a district in which there seemed to be a promising source of iron-ore awaiting development.

The examination of boreholes in progress could not however be suspended, either in England or Scotland, without risking the loss of valuable information.

The initiation of the series of 'Special Reports' referred to was briefly recorded in the Summary of Progress for 1915, p. 1. During that year the first three volumes of the series were published, and in 1916 these were followed by Vols. 4 and 5.

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During 1916 also the field-work connected with the wide subject of refractory materials was completed, an extensive series of specimens was collected, and the petrological and chemical examination of them was put in hand. At the same time an enquiry into the resources of iron-ore in Britain was commenced. Second editions of three of the volumes were required before the end of the year.

The scope of these publications, and the nature of the work required for their preparation, are indicated by the following extract from the preface of Vol. 1:—

"The method of occurrence and the exploitation of minerals in Britain have already been described by the Geological Survey in various District Memoirs and Explanations of the sheets of the one-inch maps, but in each case the information relates only to the areas dealt with in the Memoir. The Iron Ores of Great Britain, published in 1856-62, the more recent Handbooks to the Collections of Gemstones, of Clays and of Pottery in the Museum of Practical Geology, the Memoirs on the Oil Shales, and on the character of the Coals of South Wales, are cases in which the economic applications of geology have formed the subject of separate publications. As regards other minerals the records are either scattered through a number of publications, or are not forthcoming in districts for which no Memoir has been prepared.

It was clearly desirable therefore to assemble all the information, to bring it up to date by an examination of the mines, quarries, etc., from which economic minerals are or have been produced, and to make it available in a convenient form.

The present publication is the first of a series in which these objects are being kept in view. In each volume the characters, sources, uses and methods of preparation of the minerals under consideration will be described in an Introductory Chapter. This will be followed by an account of each of the mines or quarries from which the minerals are or have been produced, together with notes on some occurrences which have not been commercially exploited. The principal points dealt with in the description of the mines are the situation, history and extent of the workings, and one of the objects has been to show, among other things, where minerals of value have been left in old workings, as well as where they may be expected to occur in untouched ground.

At the same time brief notes are given on possible obstacles to further development which may arise from heavy water, difficulties in transport, or other causes."

In addition to forming a record of the particulars referred to in the above extract, these publications illustrate the variations in value of raw mineral products according to the demand created for them by new industries, or by new applications in old industries. In the first volume it is shown that ore of tungsten, which is now in keen demand, especially for the manufacture of hard steel, was formerly a waste-product, and that its prevalence in some of the tin-mines led to their being closed. Similarly barytes, dealt with in Volume 2, is now raised largely from old lead-mines, in which it was left as not worth extraction unless it contained a payable quantity of galena. Fluorspar, the subject of Volume 3, is also being raised from old lead-mines, and in some parts of the country is being picked out of the waste-heaps. In several cases barytes and fluorspar have taken the first place as the products of the mines, while galena has become a by-product, and probably would have been no longer raised had it not been associated with an accessory mineral of value. Sandstones, regarded a few years ago as

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useless save for rough building or inferior road-metal, have come into demand for refractory purposes, and sands are finding a variety of uses. The lesson is impressed that exhaustive investigation should be made of all rocks and minerals, irrespective of their commercial value at the moment.

As regards resources in Britain, the result of the investigation has proved satisfactory in the case of some of the minerals so far dealt with. Of such products as barytes and witherite, gypsum and anhydrite, fluorspar, sandstones and sands, the reserves of all except a few of the finest and most exceptional qualities, are ample. On the other hand the occurrences of tungsten-ores, celestine, graphite, molybdenite, chromite, steatite and diatomite are strictly limited, while the cost of home-production of phosphatic minerals rendered them unfit to compete commercially with foreign material. The production of the finest qualities of such materials as barytes, fluorspar, calc-spar and glass-sands is partly dependent upon the care which is devoted to selecting and preparing them, which itself depends upon the price obtainable. In some cases, such as sands for glass-making and other purposes, the relative cost of transport by rail or water becomes a determining factor in the use of British or foreign material. Home-resources of all but the exceptional qualities, however abundant they may be, will not be fully utilised so long as they cost the manufacturer more than the foreign material.

The distribution of the economic minerals is fully set out in the 'Special Reports.' That, so far as regards those deposited from solution under normal conditions (metasomatic replacement), it was determined by local circumstances is clear, but it seldom appears what those circumstances were. Barytes, for example, is the principal spar in veins in Carboniferous Limestone in Teesdale, while fluorspar is the principal spar in veins in the same formation in Weardale. Derbyshire is a well-known centre for fluorspar and barytes in Carboniferous Limestone, yet in Flintshire that formation yields little of either mineral. Moreover, in Derbyshire, the fluorspar is more or less confined to the eastern margin of the limestone-tract. It tends, also, to occur in the uppermost beds of the limestone, and to be replaced downwards by barytes and calcite.

Similarly the ores of lead and zinc are concentrated within certain districts, irrespective of the fact that the strata which are productive within those districts extend beyond them, apparently under equally favourable circumstances. This observation applies equally to the Carboniferous Limestone and to the Lower Palæozoic rocks. In both, the ore-fields are capable of a more or less precise definition, but the reason of their being limited and situated where they are is not known.

The distribution of quartz as an infilling of veins is less difficult of explanation. It frequently shows a connection with the distribution of the more siliceous rocks through which the veins pass, and the inference follows that the siliceous vein-stuff has been derived more or less directly from the neighbouring country-rock. This explanation is not available in the case of

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such minerals as barytes and fluorspar, which must have been derived from some more distant sources. That different sources were laid under contribution for vein-fillings at different times is proved by such a case as that which has been observed in Flintshire. The east-and-west veins yield a galena in which silver exists in payable quantity, and zinc-blende; the north-and-south veins, which appear to be of later date, contain galena almost devoid of silver but show traces of copper, and yield no zinc-blende. The area of productiveness is nevertheless the same for both classes of vein. The original source of the mineralising solutions is known in none of the cases mentioned, but it is to be noted that the waters appear to have penetrated from above downwards, and that all the ingredients of vein-products in the Carboniferous Limestone have been recorded in Coal Measure waters.

In the Lower Palæozoic rocks the occurrences of barytes in and near Shropshire, of lead-ores at Leadhills and Wanlockhead, in Scotland, are examples among many that could be quoted, of concentrations of minerals and ores in certain definable areas. That the dimensions of a vein may be dependent upon the capability of the rock it traverses to maintain an open fissure, is obvious, but these and other conditions appear to exist as fully outside the areas to which the ores are confined as within them.

The distribution of bedded minerals and ores is no less difficult to explain. In the Keuper Marl gypsum-deposits are interbedded at approximately the same horizon throughout a considerable part of the country, yet in one limited area in Gloucestershire and Somerset sulphate of strontia takes the place of, or has been crystallised out with the sulphate of lime, as described in Volume 3. Again, the reason for the localisation of such a deposit as that of carbonate and silicate of manganese, described in Volume 1, which is interstratified in the lower part of the Cambrian rocks of North Wales, is still to seek. That deposition of manganese ores is not unknown elsewhere at about the same horizon does not explain the exceptional concentration which took place in Merioneth.

The raw materials which are used in the manufacture of refractory products and which will form the subject of the next volume of the 'Special Reports,' come under a different category. Those which have engaged the attention of the staff in 1916 include quartzites, quartzitic sandstones, ganisters, sands and siliceous clays (fireclays). All these occur as beds in the series of sedimentary formations, and are accessible at their outcrops for determination of their characters, thickness and range. They exist in great quantity and variety in Britain, several of them in one part or another of the Carboniferous system. With the exception of dolomite they all fall under the description of acid refractories. Dolomite is abundant in this country, but other basic refractories are imported.

The silica-brick was first manufactured in 1822 at Dinas, in South Wales, though the raw material had been used in furnaces in copper-works several years before. The method, which

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was long kept secret, consisted of mixing silica-rock, crushed or naturally disintegrated, with about one per cent. of lime, enough water to make it coherent, moulding, drying and firing.[1] The Dinas silica-rock is obtained from the basal grit of the Millstone Grit.

In Yorkshire the outcrops of the sandstones and shales which compose the Millstone Grit were laid down upon the six-inch maps many years ago. These maps have now become the chief guide to the laying-out of works for the production of silica-rock.

Refractory sand of high silica percentage, used in large quantities for furnace-hearths and other purposes in the steel industry, was obtained before the war principally from Holland and Belgium. Some British sands occurring mainly in the Lower Greensand and Oolitic formations are found to be suitable for the purposes. The chief resources have been investigated during the year by Mr. G. W. Lamplugh in East Yorkshire, Norfolk, Bedfordshire and Buckinghamshire.

In Scotland the silica-brick industry was started about the year 1876. Flints from Antrim, from the Thames, and from the North of France were used, with a bonding material of plastic clay from South Wales, and until recently little inquiry had been made for Scottish materials. Ganisters and fireclays are now worked extensively, especially in the Central Valley, but it is doubtful whether any of these are equal in quality to the best English ganister. Several rocks not now worked, including sandstones and ganisters in the Lower Carboniferous groups and quartzites in the older formations, have been examined and appear likely to give good results.

For hearth-sand material imported from Belgium was used in Scotland almost exclusively, but various sandstones are now ground, and, in addition to Dutch sand, are serving as substitutes for the Belgian material.

II.—FIELD WORK.

In the following brief summary of the results of the field-work of 1916, it will be shown that the raw materials now in use for the manufacture of silica-bricks and other refractory products occur in great variety in several formations and are distributed through a large part of Britain. For their investigation the country was divided into:—

(1) The North-East of England, with Derbyshire, Yorkshire (West Riding), Nottinghamshire, Leicestershire and Warwickshire, Lincolnshire.

W. Gibson, D.Sc., District Geologist.
C. B. Wedd, B.A.
R. L. Sherlock, D.Sc., A.R.S.M. } Geologists

[1] Percy, 'Metallurgy,' 1875, p. 146.

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(2) Cumberland, Yorkshire (Ingleton Coalfield), Lancashire, Cheshire and North Staffordshire, Denbighshire and Flintshire, Anglesey, Shropshire, Worcestershire, South Staffordshire, Gloucestershire, South Wales and Monmouthshire, Cornwall and Devon.

T. C. Cantrill, B.Sc., District Geologist.
H. Dewey. } Geologists.
B. Smith, M.A. }
J. Pringle. Assistant Palæontologist.

In both Districts (1) and (2) Mr. Howe visited the principal steel works and collected information as to the trade requirements as regards refractories, and the sources of the raw materials. Mr. Pringle assisted in the examination of the Forest of Dean and of the South Wales Coalfield.

(3) Scotland.

Investigation of refractory materials.

L. W. Hinxman, B.A., District Geologist.
M. Macgregor, M.A. } Geologists.
G. V. Wilson, B.Sc. }

The Dalry Ironstone Field, Ayrshire.

C. T. Clough, M.A., LL.D., District Geologist.
C. H. Dinham, B.A. } Geologists.
G. V. Wilson, B.Sc. }

(1) The North-east of England, with Derbyshire, Yorkshire (West Riding), Nottinghamshire, Leicestershire and Warwickshire, Lincolnshire.

THE NORTH-EAST OF ENGLAND (NORTHUMBERLAND, DURHAM AND NORTH YORKSHIRE).

Silica- and ganister-bricks are manufactured somewhat extensively. Fireclay bricks are produced in large quantity, but they are not, as a rule, of a highly refractory character. Some clays, however, furnish firebricks suitable for the outer parts of furnaces. Magnesite-brick is made in comparatively small quantity from imported material, and chrome-brick in still less quantity. Several refractory sands for the purposes of iron- and steel-works are obtained in the district; but those most used are brought from distant parts of England or imported from abroad.

Ganisters and silica-rocks.—About 15 different beds of ganister and silica-rock are used for making refractory bricks. These beds range from the upper part of the Carboniferous Limestone Series (Calcareous Group) upwards into the Lower Coal Measures, while one or two are worked in the Oolites of North Cleveland. None are associated with workable coal-seams.

There is an abundant supply of these materials, but limited

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for practical purposes to such areas as afford transport facilities, Weardale being the chief source. At present, however, dearth of labour tends to counteract this abundance.

Few of these rock-beds are worked at more than one or two localities, and other beds of silica-rock could doubtless be found in the district.

Fireclays.—Firebrick is made from several good fireclays in the Lower Coal Measures below the Brockwell Coal and in the lower part of the Middle Coal Measures, the clays for the most part being associated with coals raised at the collieries. Some fireclay is obtained also from the upper part of the Carboniferous Limestone Series.

Firebrick is often made only for the sake of utilising a waste product of coal-mining. An abundant supply of clay is assured so long as the associated coal-seams are worked, and it is likely that other fireclays might be used.

Several moulding sands of Permian, Oolitic and Glacial ages are obtained in this district.

The dolomite used is obtained from a small area near Coxhoe. Its occurrence in the Permian Limestone of County Durham is capricious.

YORKSHIRE (WEST RIDING).

For variety and maximum of output of refractory goods the West Riding of Yorkshire stands pre-eminent. The bulk of the raw material is obtained from the lower part (Ganister Group) of the local Lower Coal Measures. Sheffield may be regarded as the centre of the silica-brick industry, and Leeds, Huddersfield and Halifax of firebrick.

Not only are there ample reserves in the areas at present worked, but there are many others still untouched. It should be borne in mind, however, that in passing northwards from Sheffield, the ganister below the Hard Mine Coal gradually changes its character, and over the northern part of the coal-field is more often a siliceous clay than a ganister of the Sheffield type. On the other hand the clays of the Lower Coal Measures become more regular in composition and the sandstone bands more siliceous and less felspathic. The Bunter beds furnish moulding sands, notably near Heck.

DERBYSHIRE.

No great quantity of ganister and silica-rock is raised in Derbyshire. The few rocks of these types that are used are of Coal Measure or rarely of Millstone Grit age. The Sheffield ganister (below the Hard Mine Coal of Yorkshire and Alton Coal of Derbyshire) is worked at wide intervals and could probably be worked more extensively as far south as Ambergate, southward of which it passes into fireclay. It is present in the north-west of the county, but seems not to have been tried. No other ganisters or silica-rocks are worked south of the neighbourhood of Ambergate.

Comparatively little fireclay is used for refractory purposes.

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A bed underlying the Sheffield ganister is used locally in the manufacture of ganister-brick, as is the under-clay of the Deep Hard Coal (Middle Coal Measures), with admixture of ganister sand, for making coke-oven bricks, and alone for "botting" blast furnaces.

The pockets of sand and clay which occur in the Carboniferous Limestone at numerous points in the elevated tract between Alsop Moor, Brassington and Parsley Hay are being actively worked mainly for the production of siliceous firebrick. The white or pale-grey argillaceous sands are also distributed in bulk to steelworks. Occasionally some of the more plastic white sandy clays are picked out and supplied to makers of stoneware and similar goods. In normal times it might be worth while to pay more attention to these clays for special purposes. There are large reserves of the sand and clay in this district. The material in similar pockets on the Weaver Hills in Staffordshire exhibits clearer evidence of Triassic origin than that on the Derbyshire side; it is used for the manufacture of siliceous firebricks at Oakmoor.

Preparations are being made to work the large mass of dolomitised Carboniferous Limestone at Harboro' Rocks (near Brassington), and in the immediate neighbourhood as a source of dolomite. The reserves are very large and the quality is reported to be good.

NOTTINGHAMSHIRE.

Although the dolomitic part of the Permian Formation forms a broad and continuous outcrop from near Nottingham northwards, it is only in a few places, as at Steetley, near the northern border, that it is used as a refractory material. The lower part of the Bunter formation is a well-known source of moulding sands at Worksop, Mansfield and near Nottingham; the upper part is used at Retford.

LEICESTERSHIRE, WARWICKSHIRE.

The only important refractory material in Leicestershire is a fireclay in the upper part of the Middle Coal Measures. This fireclay, which is associated with others not used for refractory purposes, provides both first-class firebrick and crucible clay. The crucible clay is regarded as of better quality when mined. Both the manufactured firebrick and the raw crucible clay are supplied extensively to the Sheffield, the northern and other districts. Reserves are abundant.

The Hartshill quartzites of the Nuneaton District were examined as a possible source of a silica-rock.

LINCOLNSHIRE.

Sandy clays of the Upper Estuarine Series are employed at ·uford as a basis for the manufacture of general fireclay- s and gas-retorts.

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(2) Cumberland, Yorkshire (Ingleton Coalfield), Lancashire, Cheshire and North Staffordshire, Denbighshire and Flintshire, Anglesey, Shropshire, Worcestershire, South Staffordshire, Gloucestershire, South Wales and Monmouthshire, Cornwall and Devon.

CUMBERLAND.

Certain fireclays in the Lower and Middle Coal Measures are mined by several firms for making firebricks, furnace-blocks and stove-bricks, tuyeres for Bessemer converters, sleeves, stoppers, nozzles, and bricks for coke-ovens. The output is chiefly absorbed by steel and iron firms in Cumberland and Lancashire.

Highly siliceous fireclay, ganister and millstone grit is made up into ganister-compound. No silica-brick is produced in this coalfield.

Pig-bed and casting-sands are dug from local Glacial and sea-sands at Harrington and Workington.

YORKSHIRE (INGLETON COALFIELD).

No fireclays are raised in this field for making refractory goods; but certain under-clays are suitable for the manufacture of stone jars and flower-pots.

At Bentham a soft Millstone Grit is crushed for pig-bed sand, and a Glacial deposit is dug for moulding.

LANCASHIRE (FURNESS).

In the Furness district steel-moulding sand, occurring in pockets of hæmatite at the Park Mine, near Askham, was examined and sampled. Its value lies in the fact that it comes clean away from the casting and can be used for intricate work. Similar sand, occurring under slightly different conditions, is used for lining steel-converters. Reserves are large, and the output could be easily increased.

The sand is described by Mr. Smith as occurring in pockets (Fig. 1) in the surface of a platform of Carboniferous Limestone, which is thickly covered by boulder-clay.[1] The limestone is faulted against Skiddaw Slate on the east, and towards the south forms a steep face against which the St. Bees Sandstone (Trias) is banked. It dips south-westwards and the pockets are more or less arranged in lines in the direction of dip.

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[1] These pockets are described by J. D. Kendall in 'The Iron Ores of Great Britain and Ireland,' 1893, pp. 98, 99 and 309.

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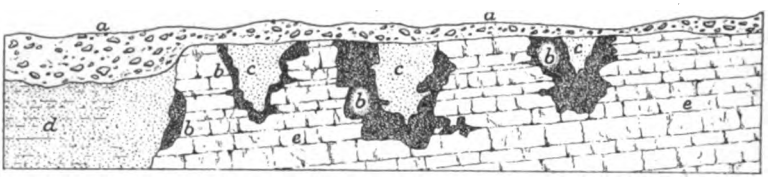
Fig. 1.—Section illustrating the occurrence of steel-moulding sands at Park Mines, Askham-in-Furness.



a. Boulder-clay. *b*. Hæmatite.
c. Sand in pockets. *d*. Trias (St. Bees Sandstone).
e. Carboniferous Limestone.

The pockets are oval to circular in plan and steep-sided. Downwards they diminish in size, often to sharp, funnel-like terminations. Their outlines, however, are most irregular, both in plan and section. A large pocket would measure about 80 fathoms in depth and 150 fathoms in greatest diameter.

They contain an outer layer of hæmatite which shows an obvious relationship in form to the walls of the pocket. Within this layer there occurs an almost continuous lining of reddish clay, varying from 6 inches to 6 feet in thickness. The central part of the pocket is filled with loose sand, with small rounded fragments or large irregular lumps of pale-grey friable stratified sandstone, all mixed confusedly together. The fragments contain occasional ferruginous, micaceous, or loamy layers and galls of clay. Near the Silurian area the pockets contain no sand; but farther from it and nearer to the red sandstone area sand gradually comes to occupy a larger part of the pocket than the ore. Both the sand and the lumps of sandstone are such as may have been derived from the St. Bees Sandstone; no other materials occur. Within 30 feet of the limestone-face referred to above, the St. Bees Sandstone is in the same fragmentary state as the material in the pockets.

The sand and the lumps of sandstone, but not the clay-lining, are crushed and mixed for use.

Pig-bed sand is obtained from Glacial deposits at Parrock Hall, north of Barrow-in-Furness; and crushed red sand from Hawcoat is used for foundry work.

Lancashire (cont.), Cheshire and North Staffordshire.

Fireclays in the Millstone Grit, and in the Lower, Middle and Upper Coal Measures, are used for the manufacture of fire-resisting goods. The industry is not centralized about any one town, but is carried on at a number of widely separated localities. Works have been visited in the following districts:—Macclesfield, Stockport, Ashton-under-Lyne, Oldham, and Bury; Bolton, Wigan and St. Helens; Blackburn and Burnley. The Lower Mountain (or Ganister) Mine Fireclay in the Lower Coal Measures is the bed chiefly used for fire-resisting goods. Other clays in the Coal Measures, and some in the Millstone Grit, have proved as a rule to be more suitable for sanitary, glazed,

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and acid-resisting wares. The so-called ganister frequently associated with the Lower Mountain Mine Fireclay is a siliceous fireclay and not a true ganister.

The reserves of fireclay are ample for present requirements and prospective developments, though a recent extension of the long-wall method of mining the coal has somewhat curtailed the output of the underclays.

The goods produced are common firebricks, and all kinds of boiler-seatings, furnace-blocks, destructor-blocks, cupola-blocks, linings for oil-furnaces, coke-oven bricks, hot-blast stove-bricks, sleeves, stoppers and nozzles, ladle-bricks, acid-resisting goods, and gas-retorts. Ground ganister is supplied to the local iron and steel works.

Moulding-sand and sand for forge-furnaces is obtained by crushing some of the siliceous sandstones in the Millstone Grit and Coal Measures; while finer varieties are obtained from the Bunter sandstones and from the Glacial and Recent deposits. Of all these there are large reserves.

Between Mow Cop and the northern end of Congleton Edge, on the Cheshire side, the siliceous sandstones or 'crowstones' of the Pendleside Series crop out from beneath the Millstone Grit and are being worked with the accompanying shales for ground ganister; the rock is also exported to other parts of the country for making silica-brick. The same sandstone is worked at Gun Hill, near Leek, for making silica-brick at Burslem. The reserves are considerable in both areas, and there are large supplies available farther north about Bosley Minn and Sutton Common, south of Macclesfield.

The clays extensively dug in the upper part of the Middle Coal Measures of North Staffordshire are used chiefly in connection with the pottery-industry.

DENBIGHSHIRE AND FLINTSHIRE.

At the southern end of this coal district the dolomite-deposits of Porth-y-waen, near Oswestry, were investigated. The rock belongs to the Carboniferous Limestone Series and is largely worked as a source of dolomite for use in the basic process of steel-making.

Farther north, near Ruabon and Wrexham, fire-resisting goods are manufactured from fireclays in the Coal Measures. The chief output, before the war, was in sanitary ware and glazed goods.

Silica-bricks are being made by an increasing number of firms from the quartzites and sandstones of the Cefn-y-fedw Series ('Millstone Grit') and from a ganister in the Coal Measures.

At Buckley some peculiar and variable fireclays at the top of the Middle Coal Measures are used mainly for acid-resisting bricks; but there is now almost as great an output of 'brindled' and white fire-resisting goods, of high strength and resistance to abrasion.

Silica-bricks are now made by one firm from siliceous beds in the Buckley Group.

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ANGLESEY.

In Anglesey, siliceous refractory materials are raised at Holyhead Mountain and at Ty-du, near Porth-wen (2½ miles W.N.W. of Amlwch). The rock at Holyhead Mountain is a quartzite, probably of pre-Cambrian age, and is capable of yielding inexhaustible supplies of the raw material. The best quality is used for the manufacture of silica-bricks; other grades are ground for ganister compound, for steel-moulding sand and hearth-sand, and for steel-moulder's paint.

The quartzite at Ty-du is to be used for similar products.

SHROPSHIRE.

In Coalbrookdale the fireclay, which is the chief refractory material, is obtained from several beds in the Middle or Productive Coal Measures, and is raised by about ten firms, mainly for the manufacture of common firebricks and saggers for use in the local potteries. Several firms engaged in the iron and steel industries make their own refractory goods.

There is apparently no shortage of raw material.

One steel and iron firm manufacture silica-bricks for their own use from a local sandstone.

Moulding-sand is obtained from the Bunter and from Glacial deposits.

Quarries in the Stiperstones Quartzite (Arenig) at Pontesbury and Granham's Moor were sampled with a view of ascertaining whether the stone can be used as a source of refractory sand. There is no lack of the raw material.

WORCESTERSHIRE.

The Lickey Quartzite of Cambrian age was sampled, as this stone has been used as a source of silica in the manufacture of certain firebricks in the Stourbridge district. There are ample reserves between Barnt Green and Rubery, where the rock is largely quarried for road-stone.

SOUTH STAFFORDSHIRE.

The chief refractory material raised is fireclay, and the manufacture of fireclay goods is concentrated in the Stourbridge district, on the borders of Staffordshire and Worcestershire. There are about six beds of fireclay of first quality and several others of inferior grade, all of which occur in the Middle or Productive Coal Measures. From these clays are produced all varieties of fireclay goods, such as firebricks of various shapes and sizes, gas-retorts, blast-furnace lining-blocks, bricks for hot-blast stoves, boiler seating-blocks, flue-covers, bricks for muffle-kilns, coke-oven bricks, glass-house tank-blocks and glass-house pots. Clay for crucibles is sold.

There appears to be no shortage of the raw material, though in some parts of the district the underground water is rising and flooding the deeper workings, and unless some comprehensive drainage scheme is adopted, there is a prospect of some of the mines being soon forced to close down.

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Common red moulding-sand is extensively raised from the Upper Mottled Sandstone (Bunter) between Stourbridge and Wolverhampton, but no highly refractory sand was met with.

GLOUCESTERSHIRE (FOREST OF DEAN).

Only one firm is engaged in the manufacture of firebrick goods. These are produced from some sandstones at the top of the Millstone Grit near Coleford, and appear to be intermediate between firebrick and silica-brick.

Though the Carboniferous Limestone that surrounds the coal basin appears to be considerably dolomitic, especially on the eastern side, no dolomite for the basic steel process is produced. In one locality the limestone has been proved by analyses to be too siliceous for this purpose. Other quarries have been sampled with a view to ascertaining whether the same siliceous character prevails elsewhere.

SOUTH WALES AND MONMOUTHSHIRE.

In this district silica-bricks are the chief refractory product, firebricks being less important.

The silica-bricks are made from the quartzites of the Millstone Grit, the stone being raised at or near Dowlais, Hirwaun, the Vale of Neath, the Vale of Tawe, the Black Mountain (near Brynamman), Llandybie (near Llandilo), Kidwelly, and Templeton (near Narberth). The same formation yields also materials for ground ganister and hearth-sands for steel-furnaces. There are inexhaustible reserves.

The fireclays occur in the Lower Coal Series and Pennant Series of the Coal Measures. They are manufactured into ordinary firebricks, blast-furnace blocks, blocks for steel- and zinc-furnaces, cupola-linings, boiler-seatings, coke-oven bricks, hot-blast stove-bricks, flue-covers, ladle-bricks, sleeves, stoppers and nozzles, tuyeres, &c., &c. Ground fireclay is supplied for ladle-linings and for use in copper-, zinc-, and tin-works.

Though much of the Carboniferous Limestone on the eastern and south-eastern margins of the coalfield is dolomitic, none of it is yet worked for use in the steel-furnace hearths or converters. It remains to be proved whether it is sufficiently rich in magnesia and free from silica. A local development of dolomite at Clydach, near Abergavenny, promises to be suitable for this purpose, though the reserves are limited.

There are no important deposits of moulding-sand in South Wales, but suitable material is manufactured from the disintegrated quartzites and sandstones of the Millstone Grit, or imported from the Bunter districts of Staffordshire and Worcestershire.

Hearth-sands are obtained from the disintegrated quartzites and sandstones of the Millstone Grit, and in one case from quartzites in the Old Red Sandstone.

CORNWALL AND DEVON.

Firebricks are made from disintegrated granite.

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(3) Scotland.

The general results of the investigations in Scotland may be stated briefly as follows:—

Hearth Sands.—The holding up of the supply of natural Belgian sand, used almost universally before the war for open-hearth acid steel-furnaces and linings of converters in the Bessemer process, has created a large demand for sand suitable for this purpose. This has been met by the importation of a limited amount of Dutch sand, and by the use of ground sandstone from different localities in the South of Scotland. These sandstones, which are chiefly of Millstone Grit and Carboniferous Limestone age, have a high silica-content, but apart from their chemical composition produce, when ground, a sand inferior in physical characters to the round, even-grained, natural Belgian product.

It is indeed believed by the users that no Scottish sand, hitherto produced, can compete, either in quality or price, with the Belgian sand as obtained under pre-war conditions; it is thus probable that these sandstones may have only a temporary value as a source of hearth-sand.

Ganister and other material for Silica Bricks.—There is a constant and increasing demand for bricks equal in quality to the best Sheffield and Welsh silica-bricks for use in steel and other high-temperature furnaces; those at present made from Scottish ganisters being for the most part not sufficiently resistant to be used in the vital parts of such furnaces.

Silica-bricks were at one time manufactured by the Eglinton Silica Brick Co., Ltd., Glasgow, from chalk-flints brought from Antrim, the Thames, and the northern coast of France. The material for silica-bricks now being made in Scotland is chiefly derived from the 'ganisters' or siliceous sandstones associated with the Upper and Lower Fireclays of the Millstone Grit of Lanarkshire and Stirlingshire, and also, to a small extent, from sandstone of Carboniferous Limestone age. A ganister lying near the base of the limestone series along the borders of Edinburghshire and Peeblesshire has lately been analysed and tested and seems likely to yield refractory material of high quality, the silica-content of some of the samples being up to 98·8 and 99·4 per cent. This ganister is about to be opened up between Carlops and Macbiehill, Peeblesshire.

Certain highly siliceous quartzites on the coasts of Islay and Jura; on the north shore of Loch Leven, east of Ballachulish; and in the neighbourhood of Dalmally, Argyllshire, have been examined by the Survey and are suggested as potential sources of material for silica-bricks. Specimens from different localities in these areas have been submitted for analysis and testing.

Samples of some of these quartzites have been tested by the Eglinton Silica Brick Co., Glasgow, and the rock from Loch Leven is regarded by them as the best suited for the manufacture of silica-bricks.

The amount of rock available at the localities mentioned is large. It lies at or close to the surface and, in the case of the first two areas, conveniently for transport by sea.

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The radiolarian cherts of Lower Silurian age at Abington in the Clyde Valley and on the Ayrshire coast near Ballantrae have been sampled for analysis with a view to their suitability for refractory material, and to these potentialities may be added a number of siliceous sandstones in the neighbourhood of Edinburgh, in Lanarkshire, Ayrshire, and the Sanquhar Coalfield, Dumfriesshire.

Fireclay.—The fireclays in the Millstone Grit of Lanarkshire and Stirlingshire have long been known as a source of material for high-class refractory products. These include bricks and blocks for use in the crowns and linings of steel-, glass-, and chemical furnaces; for coke-ovens, gas-retorts, kilns, oil-furnaces (locomotive and marine); nozzles and stoppers and other fireclay-goods.

The clays are derived from two horizons in the Millstone Grit —the Lower Fireclay near the base, and the Upper Fireclay in the upper part of the series.

There are ample reserves of material in sight to meet all present demands, while large fields, especially of the Lower Fireclay, are as yet almost untouched.

Clays of secondary quality at the base of the Coal Measures near Falkirk; in the Calciferous Sandstone of Renfrewshire, and beneath the coal-seams in several localities in the Central Valley, Ayrshire and Fife are also used in the production of ordinary fireclay-goods. The fireclays of North Ayrshire have been the subject of recent investigation by the Survey and seem likely to yield material of high refractory value. The Ayrshire clays also occur at two horizons—above and below the Millstone Grit lavas. The Lower Fireclay is mined at Monkcastle, Dalry, and provides bricks and blocks for local use in steel-, iron- and zinc-furnaces; the more varied shapes are sent to London for special purposes.

The Upper Fireclay of Ayrshire, which has been traced from the shore at South Bay, Saltcoats, eastwards towards Kilmarnock, is peculiar in being very hard and well jointed, and having a conchoidal fracture. It also contains an unusual proportion of alumina, sometimes as high as 47·5 per cent. Oxide of titanium, usually in the form of rutile, is also abundant. This clay has been analysed and tested, but is not yet worked. It is worthy of consideration as a clay with a high percentage of alumina.

Dolomite.—The dolomite at present used in basic steel processes in Scotland is chiefly derived from the Magnesian Limestone of the North of England. Considerable areas of dolomite of Cambrian age are found in West Sutherland, West Ross, and near Broadford in Skye, but the quality of the stone does not appear to be high enough to meet the cost of carriage from these remote regions.

A dolomite-band of the Appin Limestone, one of the members of the Lochaber Series of metamorphic rocks, has recently been opened up at Duror, in Appin, North Argyllshire. Hand-samples of the rock have been analysed and reported on as likely to give quite a good dolomite after burning. A large demand and output would, however, be necessary to cover the cost of

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production and carriage, and to allow the material to be put on the market at a price approaching that of North of England dolomite.

Magnesite-bricks are now being made on a large scale to meet present demands by the Eglinton Silica Brick Co., Glasgow, but entirely from imported material.

The Dalry Ironstone Field, Ayrshire.

Following upon an increasing demand for iron-ore in Scotland, the late Dr. Clough, after examining the plans of old hæmatite-mines, decided that, under existing conditions, the Dalry field in Ayrshire was one of the most promising sources of ironstone. Mr. Dinham and Mr. Wilson, acting under Dr. Clough, as District Geologist, were accordingly detailed to make a revision of the six-inch sheets of that district. Mr. Dinham examined the ground north of a line passing east and west through Glengarnock, while Mr. Wilson revised the maps to the south of this line.

In the area revised by Mr. Dinham, a considerable advance in detail was made on the original survey, and the following average sequence was established with the aid of the various natural sections and bore-journals, and of the exposure in the cutting of the North Johnstone Loop Line of the Glasgow and South Western Railway.

	Thickness.			Depth below Index.		
	Fms.	ft.	in.	Fms.	ft.	in.
Index Limestone	0	4	10	0	0	0
Strata mostly fireclay and fakes	6	3	0	6	3	0
Dirty Coal 4 in. to 12 in....	0	0	8	6	3	8
Sandstone and fireclay	0	4	0	7	1	8
Kilbirnie Wee Coal	0	2	3	7	3	11
Sandstone and fakes	3	3	0	11	0	11
Blaes, with *Lingula* near base	3	0	0	14	0	11
Kilbirnie Smithy Coal 3 ft. to 3 ft. 6 in. ...	0	3	3	14	4	2
Fireclay and sandstone	1	4	0	16	2	2
Kilbirnie Main Coal 4 ft. to 5 ft.	0	4	6	17	0	8
Sandstone and fakes	3	0	0	20	0	8
Kilbirnie Stone or Stoney Coal 2 ft. 11 in. to 3 ft. 3 in.	0	3	1	20	3	9
Sandstone and fakes	1	4	0	22	1	9
Coal or Coaly Blaes 1 ft. 3 in. to 1 ft. 6 in. ...	0	1	4	22	3	1
Strata, about	7	0	0	29	3	1
Borestone Coal	0	4	2	30	1	3
Strata	2	1	0	32	2	3
Coal 1 ft. to 1 ft. 6 in.	0	1	3	32	3	6
Sandstone and fireclay	1	2	0	33	5	6
Blaes with thin ironstone ribs	3	0	0	36	5	6
Sandstone 1 ft. to 2 ft.	0	1	6	37	1	0
Weir Coal 6 in. to 11 in.	0	0	9	37	1	9
Sandstone and fakes	2	1	0	39	2	9
Irony parrot with *Lingula*	0	0	4	39	3	1
Sandstone and fakes	2	1	0	42	4	1
Faky blaes and blaes with ironstone ribs	3	0	0	44	4	1
Fakes and sandstone	2	3	0	47	1	1
Newfaulds Coal	0	0	11	47	2	0
Strata, mostly fakes and sandstone ...	8	3	0	55	5	0
Faky blaes	4	0	0	59	5	0

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	Thickness.			Depth below Index.		
	Fms.	ft.	in.	Fms.	ft.	in.
Blaes with ribs (Logan's Bands) of ironstone and limestone (5–12 in.), containing *Lingula*, entomostraca, and fish-remains	5	0	0	64	5	0
Sandstone and fakes with thin coal ...	5	0	0	69	5	0
Blaes with thin ironstone-ribs, barren ...	3	1	0	73	0	0
Dalry Blackband Ironstone position (coal and ironstone)	0	1	1	73	1	1
Fireclay and blaes with balls	1	3	6	74	4	7
Coal	0	0	4	74	4	11
Sandstone	0	5	6	75	4	5
Maich Mussel Band Ironstone, limy, 1 ft. 3 in., in blaes with ironstone-ribs, one 10 in. (kingley)	3	0	0	78	4	5
Sandstone	4	3	0	83	1	5
Blaes	0	4	0	83	5	5
Kirnhole Coal, 4 in.—6 in.	0	0	5	83	5	10
Sandstone and fakes	5	0	0	88	5	10
Blaes	2	0	0	90	5	10
Blaes full of *Lingula* with Pundeavon Ironstone (7–12 in.) in middle	2	0	0	92	5	10
Blaes	2	0	0	94	5	10
Johnstone Shell-Bed (blaes with marine fossils) about	1	0	0	95	5	10
Blue *limy kingles* or impure Clayband Ironstone, about	0	2	0	96	1	10
Blaes	0	4	0	96	5	10
Clayband-ironstone rib	0	0	3	97	0	1
Blaes, 2 fms. in south; towards north fakes and sandstone come in here and increase the thickness to about 8 fms., average...	5	0	0	102	0	1
Dalry Main Clayband Ironstone, 13–20 ins. ...	0	1	5	102	1	6
Grey blaes with entomostraca, 3–12 ins. ...	0	0	8	102	2	2
Blaes mostly barren	3	0	0	105	2	2
Blaes with *Lingula*, and at base *Posidonomya corrugata*	4	3	0	109	5	2
Top Hosie Limestone and marine fossils (Limestone D), up to	0	0	10	110	0	0
Blaes with a slaty rib full of *Posidonomya corrugata*	0	3	0	110	3	0
Lillie's Limestone (Limestone C), 1 ft. 7 in. to 2 ft.	0	1	9	110	4	9

The Index Limestone is seen only in the railway-cutting. The main basin of the Kilbirnie Coals lies in the neighbourhood of Glengarnock, and has been mostly wrought out. A small basin was also wrought long ago in the neighbourhood of Kerse Farm, but the revision shows that an upthrow fault of about 50 fathoms runs east and west through the first bridge north of the viaduct over the Maich Water, so that the Kilbirnie Coals are thrown off to the north of this fault, unless some of them occur near the surface in a small area a little south-east of Newfaulds steading. This area is believed to lie in the deepest part of the basin, but its extent depends on the unknown prolongation of the big upthrow which runs south-west through Lochside station.

Logan's bands take their name from the proprietor of an old pit where they are said to have been wrought long ago near Baillieston, Kilbirnie. It is believed that the pit was a failure, but from what cause is uncertain. Where exposed elsewhere, as in the Paduff burn just above the Largs road, the seams themselves

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are clayband ironstones of a fair quality. Some of the bands are also seen in the cutting south-west of West Lochridge steading. Other exposures occur in the Millbank Burn, one mile S.W. of Lochwinnoch, but the ironstones here are much more limy.

The Dalry Blackband Ironstone has been wrought at Glengarnock, but was inferior in quality and thickness to the same seam further south. North of Glengarnock it rapidly deteriorates and becomes, so far as is known, quite worthless.

The Maich Musselband Ironstone is a constant horizon in the district, being known at Wheatyfauld, in the Maich Water, and in the railway-cutting on the east side of Lochwinnoch Loch. It is possible that the old pits at the loch-side were opened in this seam.

The Pundeavon Ironstone is seen well in the Pundeavon Burn, 9 inches thick, and is also exposed in the Paduff Burn, and in the Maich Water N.W. of Nervelston, where it is ten to thirteen inches in thickness. It is apt to contain ribs of poor limy ironstone with cone-in-cone structure. The 'Garibaldi' Ironstone, wrought as recently as 1914 at Glengarnock, is believed to be the same seam, but this has not yet been proved to be the case. The section of the 'Garibaldi' Seam in No. 7 Pit was:—

Ironstone ("Tops")	5 inches.
Blaes	12 inches.
Ironstone ("Bottom stone") ...	4 inches.

The Johnstone Shell-Bed is a constant horizon throughout the district, though the marine fauna is not everywhere abundant. It would prove a valuable index to the Dalry Clayband in diamond or shot bores. The peculiar limy kingles which underlie the shell-bed seem to be almost as constant, and have been met with in several chisel-bores to the Clayband.

The Dalry Clayband Ironstone has not been much wrought hitherto in the district except at Glengarnock. It is well exposed in the Gowkhouse Burn near its confluence with the Pitcon Burn, and in the Paduff Burn, averaging 14 to 15 inches thick. It is not again exposed further north except in the Lora Burn, 350 yds. S.E. of Glenlora Bridge, where it is not less than 13 inches. Old bores on Gavelmoss, where it appears to have been wrought on a small scale, record a thickness of 14 to 21 inches, the seam being in two plies separated by a few inches of blaes. This ironstone could be proved by a shallow bore in the Pundeavon Burn (where it should be about 12 fathoms below the Pundeavon Ironstone) 100 yds. S. of the Kilbirnie Filter Beds; and in the Maich Water, where a bore in the corner of the L-shaped bend, 300 yds. S.W. of High Langstilly should find the Clayband at less than 10 fathoms depth. The thickness of this seam in No. 7 Pit at Glengarnock averaged 18 inches. In No. 6 Pit it was 16½ inches and divided by blaes-partings into three ribs.

Mr. Wilson reports that in the district revised by him there are three ironstones which may be considered as of economic

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importance, namely, the Dalry Clayband, the Dalry Blackband, and the Ironstones associated with the lavas of the Millstone Grit Series.

Dalry Clayband Ironstone.—To the North of the large boundary-fault which runs from Ardrossan in a north-east direction past Monkcastle and along the course of the Dusk Water the Clayband Ironstone may usually be considered as workable. It varies in thickness from 11 to 16 inches. To the south of this fault, the thickness is much less, being only 5 or 6 in. near Monkredding. The present workings on the Blair Estate south of Dalry show that this thinning occurs as the fault is approached from the north.

The Clayband Ironstone has been wrought to a large extent on the south side of the Garnock Water between Dalry and Dockra. A fairly extensive field on the estates of Kersland and Maulside is as yet untouched, and small basins also occur north and south of the Powgree Burn between Manrahead and Coalburn.

At the present time the ironstone is being wrought by W. Baird & Co., at one pit on the Blair Estate, and by Merry and Cunningham, Ltd., at Birsieknow and Dockra.

On the north side of the Garnock Water the Clayband Ironstone has been wrought at a few localities only, notably at Pitcon, Ryesholm, Mossend and Mains. A large untouched field extends from Girthill and Caddell through Burntongues and Swinlees towards Kilbirnie. The *Dalry Blackband Ironstone*, now practically worked out, has been wrought in this area on an extensive scale; these old workings are only about 30 fathoms above the Clayband Ironstone and are now full of water. On this account a considerable amount of pumping and draining would be necessary before the clayband could be worked in many parts of the district. The thickness of the Clayband Ironstone varies from 11 in. near Girthill to 14 or 15 in. near Balgry; an average thickness of 12 in. would give about 10,000,000 tons of unwrought Clayband Ironstone in the district.

Millstone Grit Ironstone.—Highly ferruginous beds have long been known to occur near the top of the Millstone Grit Lava Series in North Ayrshire. In the course of the investigation a number of exposures of these rocks were visited and specimens taken for analysis. The beds vary from 3 ft. to 8 ft. in thickness, and the material is generally a highly decomposed basic lava-flow or flows consisting of a whitish-green or brown base with numerous scattered grains of carbonate of iron (sphaerosiderite). In a few instances the colour is deep-red owing to the carbonate being reduced to the oxide. In some cases the bed is fairly homogeneous throughout, in other cases doggers and strings of good ironstone occur scattered through a ferruginous clayey matrix.

The analyses show that though these beds often contain a fairly high percentage of iron they are rich in silica and alumina, and consequently would be too costly to use as a source of iron under present conditions. It appears that the few occurrences where the ironstone is good, as at the Brackleheugh (Breakplough),

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¼ mile north of Stevenston, must unfortunately be regarded as local enrichments of no great extent.

Messrs. Macgregor and Wilson visited the ironstone bearing rocks of Garron Point, north of Stonehaven. On the south side of the Highland Boundary Fault, an area about 100 yds. wide by ½ mile in length is occupied by a suite of lava-flows and interbedded sediments dipping at an angle of about 40° towards the fault. The ironstone occurs as bands from 1 in. to 6 ft. thick throughout the series, and consists mainly of finely comminuted magnetite and hæmatite in a siliceous matrix. Several specimens were collected for analysis, and the results show that these beds are too rich in silica to be of much value as ordinary iron-ore, while they are too high in phosphorus to be used in the manufacture of ferro-silicon.

Analyses of Dalry Clayband Ironstone, Ayrshire.

1. Gowkhouse Burn, Balgry Farm (top ply).[1]
2. „ „ „ „ (bottom ply).[1]
3. Powgree Burn, ½-mile S.E. of Longbar (16 in. thick).[1]
4. „ „ ¼-mile N.E. of Coalburn (16 in. thick).[1]

—	1.	2.	3.	4.
Iron	29·17	28·81	27·09	24·12
Silica	9·30	10·30	11·50	10·
Alumina	4·67	4·15	4·50	6·43
Phosphorus ...	·56	·55	·698	·656
Sulphur	·073	·087	·192	·189
Lime	7·33	7·56	8·72	12·64
Manganese oxide...	2·14	1·95	1·48	1·58
Magnesia ...	3·90	4·20	3·92	3·24
Loss on ignition ...	29·60	29·20	28·50	29·80

Analyses of Millstone Grit Ironstone, Ayrshire.

1. Brackleheugh (Breakplough), ¼-mile north of Stevenston (from a 4-ft. seam).[1]
2. Glen Burn, ¼-mile north-west of Corsinkell and 1¼-miles north of Stevenston. Top seam 12 in. to 18 in. thick.[1]
3. Same locality. Bottom seam (6–7 ft. thick).[1]
4. Same locality. Thin veins in Bottom seam.[1]

—	1.[2]	2.	3.	4.
Iron	42·43	28·20	17·16	33·10
Silica	15·	10·60	18·70	10·50
Alumina	9·80	14·70	27·70	9·
Phosphorus ...	·061	·022	1·89	·044
Sulphur	·020	·275	·110	·046
Lime	·70	2·48	2·03	1·48
Manganese oxide...	·465	·28	·18	1·20
Magnesia	·28	3·42	2·45	2·77
Loss on ignition ...	11·50	26·80	23·40	27·80

[1] By favour of Messrs. D. Colville & Sons, Glengarnock.
[2] See also p. 24.

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Analyses of Ironstone from Garron Point.

Specimen No.	2.[1]	3.[1]	6.[1]	7.[1]
Iron	35·56	43·96	40·32	33·04
Silica	34·30	24·40	31·80	42·40
Alumina	4·70	2·60	0·90	3·10
Phosphorus ...	0·68	1·32	0·766	0·541
Sulphur	0·120	0·137	traces	0·041
Carb. of lime ...	1·80	4·82	2·68	4·70
Manganese ...	0·48	0·64	0·24	0·32
Insoluble	39·00	27·00	32·70	45·50

An old quarry in the Ochil Hills about ¾ mile from Menstry Station and 600 ft. above the level of the valley was noted by Mr. Wilson to be in a vein of calcite about 11 ft. thick. Samples taken for analysis gave the following result.

Analysis of Calcite, Menstry, Ochil Hills.

	Per cent.
Silica	·40
Oxide of iron	·36
Alumina	·34
Lime	55·
Magnesia	·60
Sulphur	trace
Phosphorus	trace
Loss on ignition	43·30
Water	·48

The above analysis shows that the rock is an exceptionally pure limestone. Practical tests made on samples have proved that it makes an excellent bind in the manufacture of silica-bricks, but the fact that it falls to powder on calcining condemns it as a flux for blast-furnaces.

III.—PETROGRAPHICAL WORK.

England and Wales.

Petrographical work during the past year has been devoted more particularly to reporting upon the distribution of useful rocks and minerals, investigating the character of refractory materials used in the steel-trade, and reporting to other Government Departments and to the general public on a variety of scientific and economic inquiries which have arisen in connection with the War.

[1] By favour of Messrs. William Dixon, Ltd., Calder Iron Works, Coatbridge.

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In addition, Dr. Thomas has reported on rocks from North Wales and the Midlands collected by the officers of the Survey, and from the Gold Coast and Easter Island collected by private individuals.

Scotland.

The Scottish petrographical work, carried on by Dr. Thomas in the London Office, has been mainly in connection with the survey of the Ayrshire Coalfield, the study of Scottish refractory materials and the description of rocks obtained from a variety of bore-holes.

The descriptive petrology of Sheet 54 (Moor of Rannoch) has been completed.

IV.—CHEMICAL WORK.

The work of the Chemical Department has lain chiefly in the analyses made in preparation for a 'Special Report' on British Refractory Materials. Seventeen analyses of ganisters and silica-rocks, and four of fireclays have been completed during the past year. In addition four complete, and five partial analyses were made of rocks which appeared likely to prove to be of economic value.

1-ft. layer of sphaerosiderite concretions in fireclay in Coal Measure Series. No. 2 bore, Byreburn, Canonbie. 1-in. sheet 11, 6-in. sheet. Dumfries 53, SE.$^{E.}$ At depth of 13 yds., 2 ft., 6 in. About 550 ft. NE. of Byreburnfast Bridge. Slice No. 19466. Lab. No. 470.

Musselband, a fine-grained carbonaceous shale occurring below the wee coal (Coal Measure Series), about 20 in. thick, in old quarry about ¼-mile W. by S. of Church in N. part of Stevenston. 1-in. sheet 22. 6-in. sheet. Ayr 16 NW.$^{E.}$ Slice No. 19511. Lab. No. 472.

Musselband, a carbonaceous ironstone (sphaerosiderite) containing organic remains. A large portion of the rock consists of iron carbonate, showing well-developed spherulitic structure. Kilmarnock Water, 400 ft. SE. of Dean Castle. 1-in. sheet 22, 6-in. sheet. Ayr 18 SW.$^{E.}$ Slice No. 19512. Lab. No. 473.

	Slice No. ...	19466.	19511.	19512.
	Lab. No. ...	470.	472.	473.
Fe_2O_3	... ...	58·78	12·80	8·30
CaO	... ...	·98	—	—
MgO	... ...	·83	—	—
P_2O_5	... ...	·58	—	—
S	... ...	·12	—	—
C	... ...	—	2·73	—

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Whitish grey clay. A large mass cropping at surface. Treven Farm. 1-in. sheet 337. 6-in. sheet. Cornwall 19 NW. Museum No. C. 3245. Lab. No. 454.

Laminated Glacial clay from West Wales. Lab. No. 474.

—	(Museum No. C. 3245.)	—
Lab. No.	454.	474.
SiO_2	61·08	58·30
TiO_2	1·54	1·15
Al_2O_3	25·21	20·49
Fe_2O_3	·65	8·07
FeO	·20	—
MnO	·07	·12
CaO	·03	·09
MgO	·62	1·74
K_2O	5·21	3·61
Na_2O	·24	·81
Li_2O	nt. fd.	nt. fd.
H_2O at 105° C.	·38	·96
H_2O above „	4·43	4·28
P_2O_5	·12	·28
FeS_2	·08	·14
CO_2	·16	·24
Total	100·02	100·28

The top 3½ ft. of the ochre-bed which is believed to represent the Gilmerton Limestone (Carboniferous Limestone Series). South side of burn, 2,600 ft. NW. of Dryden. 1-in. sheet 32, 6-in. sheet. Edin. 7 SE.^{E} It was used formerly as a paint or wash. Lab. No. 475. ANAL. E. G. RADLEY.

The top part of an ochre-bed which represents the top part of the North Greens Limestone (Carboniferous Limestone Series). South side of burn, 2,100 ft. NW. of Dryden. 1-in. sheet 32, 6-in. sheet. Edin. 7 SE.^{E} A somewhat similar bed formerly used as a paint. Lab. No. 476.
ANAL. E. G. RADLEY.

—	Lab. No. 475.	Lab. No. 476.
SiO_2	82·75	69·76
Fe calculated as Fe_2O_3 ...	5·69	14·18
FeS_2	nt. fd.	nt. fd.
P_2O_5	·19	·27

On treating the rocks with hydrochloric acid, the following results were obtained:—

Insoluble residue... ...	89·47	78·34
Fe calculated as Fe_2O_3 ...	5·37	14·13

The specimens were dried at 105° C. before the estimations were made, because as sent in for analysis, Lab. No. 475 contained over 19% of H_2O and Lab. No. 476, over 25% H_2O.

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Ironstone bed 4 ft. thick. Rotten lava or parting between lavas in Millstone Grit Series. ¼-mile north of Stevenston. Ayrshire. 1 in. sheet 22. Lab. No. 488. ANAL. E. G. RADLEY.

Lab. No.	488.
Insoluble residue	26·09
SiO_2	·78
TiO_2	·83
Al_2O_3	5·86
Fe_2O_3	46·86
FeO	5·65
MnO	·50
(CoNi)O	·03
CaO	·39
MgO	·57
K_2O	·08
Na_2O	·49
Li_2O	trace
H_2O at 105° C.	1·50
H_2O above „	6·63
P_2O_5	·47
FeS_2	·03
C	—
CO_2	3·29
SO_3	—
Total	100·05

All iron calculated as Fe			37·21
FeS_2	„	„ S	·02
P_2O_5	„	„ P	·20

V.—PALÆONTOLOGICAL WORK.

ENGLAND AND WALES.

Work has been continued on the deep borings and sinkings in Kent. Dr. Kitchin and Mr. Pringle have examined extensive suites of specimens from the additional material collected by the latter. Mr. Pringle's summarised report on three of the borings is published in Appendix II., p. 34.

Mr. Allen has revised the nomenclature of a large series of Carboniferous fishes in the Museum. He has also rearranged and catalogued the Cretaceous lamellibranchs and gasteropods, the Mollusca from the Norwich Crag and Weybourn Crag, and the plants and molluscs from the Forest Bed.

A row of teeth of the rare fish *Edestus*, from shale in the Millstone Grit, near Huddersfield, has been presented to the Museum by Mr. E. Crowther. This exceptionally fine specimen is being described by Dr. A. Smith Woodward, F.R.S.[1]

[1] See also *Abstr. Proc. Geol. Soc.*, No. 994, Oct. 4th, 1916.

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The following specimens in the Museum have been figured and described:

IN THE PALÆONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1915. (Published 1916.)

The Fossil Fishes of the English Wealden and Purbeck Formations.

By DR. A. SMITH WOODWARD, F.R.S.

Hybodus basanus *Egerton*, pl. i, f. 1, p. 6.
„ ensis *A. S. Woodw.*, pl. ii, figs. 2-5, p. 11.
Coccolepis andrewsi *A. S. Woodw.*, pl. iv, f. 2, p. 24.
Lepidotus minor *Ag.*, pl. v, f. 8, p. 29; pl. vi, f. 1, p. 28.

A Monograph of the British Asterozoa.

By MR. W. K. SPENCER, M.A.

Caractacaster caractaci (*Gregory*), pl. ii, f. 4, p. 80; pl. iii, f. 1, p. 82.

IN THE QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY, Vol. LXXI, Part 2.

By DR. STANLEY SMITH, B.A.

Lonsdaleia duplicata duplicata (*Martin*), pl. xvii, f. 2, p. 238.
„ floriformis (*Martin*), pl. xix, f. 8, p. 250.

SCOTLAND.

The fossils added to the collection during the year have been obtained chiefly from borings in the Carboniferous areas of the Central Valley, South Scotland and Ayrshire. The strata traversed range from Coal Measures to Calciferous Sandstone, and the specimens obtained have proved useful to Dr. Lee in determining horizons. Thus in the case of a boring in the Coal Measures of the Kilmarnock district the occurrence of certain 'mussel-bands' served to corroborate other evidence as regards the horizon reached. The evidence of fossils also helped in the reading of a complicated sequence in a boring in the Canonbie district, where the presence of a fault was suspected, but could not be established on lithological grounds. In the case of other borings carried through the Carboniferous Limestone in search of the Limestone Coals, the fossils substantiated the index value of certain assemblages, as for instance in a further record of *Edmondia punctatella* in its usual position below the Calmy Limestone, and in the identification of a core of the Index Limestone by the abundance of *Productus latissimus* it contained.

VI.—MUSEUM OF PRACTICAL GEOLOGY.

The Museum was closed to the public, except for special enquiries, from March 6th. This provided an opportunity to redistribute many of the larger exhibits in the Hall with a view to increasing the available space as much as possible.

On March 14th a marble bust of Sir Archibald Geikie, O.M., F.R.S., for the preparation of which funds had been provided

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by former colleagues, old pupils, and numerous friends, was presented to the Board of Education on behalf of the subscribers by Sir William E. Garforth, and accepted by the Right Hon. J. Herbert Lewis, on behalf of the Board. On the same occasion a marble replica of the bust was presented to Sir Archibald Geikie on behalf of the subscribers by the Right Hon. Lord Rayleigh, O.M., F.R.S. The original, which was executed by Prof. E. Lantéri, has been placed in the Museum of Practical Geology.

The greater part of the year has been occupied in dealing with the materials collected during the field-investigation of the British resources of refractory rocks, sands, ganisters and fireclays. More than 2,000 samples have been collected, and these have been registered, card-catalogued and prepared for the purposes of Museum exhibition.

List of Donations during the year 1916.

Acton, A., Esq.—Two micro-slides, Bwlchgwyn Quartzite (Millstone Grit), near Wrexham.

Ashcroft, F. N., Esq.—Minerals on joint-faces, from Penmaenmawr, North Wales. (Three specimens.)

Bailey, Sec.-Lieut. E. B., R.G.A.—Thirteen rock-specimens from Drake's Island, Plymouth Sound.

Barclay, Lieut., The Executors of the late.—Six *Micrasters* and two *Conulus* from the Upper Chalk of Kent and Surrey.

Barrow, G., Esq., F.G.S.—Three micro-slides of rocks, from Anglesey.

Brown, G. F., Esq.—A specimen of *Ventriculites radiatus* Mant. from the Upper Chalk of Haling Pit, near South Croydon.

Buckman, S. S., Esq., F.G.S.—An ammonite from the Lower Fuller's Earth of the Dorset Coast.

Butterworth, F. M., Esq.—Fragment of coal with impression of *Lepidophloios laricinus* (Sternb.).

Carus-Wilson, C., Esq., F.R.S.E.—A Silurian gasteropod from Shucknall, Herefordshire.

Colonies, The Under-Secretary of State for the.—Two micro-sections of kerosene shale with *Reinschia australis*, one from New South Wales, the other from West Falkland.

Crowther, E., Esq.—A row of teeth of *Edestus* from Millstone Grit shales at Brockholes, near Huddersfield, Yorkshire.

Draper, D., Esq., M.I.M.M.—Diamond, small crystal, from Agua Suja Mine, Bagagena Minas, Brazil.

Faber, H., Esq.—Diatomaceous clays from Denmark.

Farnley Iron Works Co., Ltd., Messrs. the.—Refractory materials.

Gallewski, B., Esq.—Zircon, also two samples of Graphite from Madagascar.

Greenly, E.—Thirty rock-specimens and sections from Anglesey.

Hamling, J. G., Esq., F.G.S.—A series of Devonian and Culm fossils from North Devon.

Heron-Allen, E., Esq., F.L.S., F.R.M.S.—A specimen of Alveolina (Mixen) Rock, in the soft state, from Selsey Bill, Sussex.

Howe, J. Allen, Esq., B.Sc.—A specimen of *Alveolites septosus* (Flem.) from the Carboniferous Limestone of Monsal Dale, Derbyshire.

Johnston, Miss Mary.—Portion of a brick made from "Âs" sand, Kallbohn, Sweden.

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KING, CAPTAIN W. B. R., B.A.—A series of fossils and rock specimens from Chloritic Marl, Chalk and Tertiary Beds of Northern France. A series of specimens, mainly rocks, from the Western Front (North France).

LAMPLUGH, G. W., ESQ., F.R.S.—A series of fossils from the Greensand of Shenley Hill, near Leighton Buzzard, and other Cretaceous specimens from Faringdon, etc.

LANGSLOWLOCK, E. A., ESQ.—Topaz from Tin washings, Nigeria.

LAWRENCE, L. A., ESQ.—A small cut purple diamond.

MARR, DR. J. E., F.R.S.—Two specimens of metalliferous vein, metamorphosed by Shap granite.

MOULDEN, J. C., ESQ., M.I.M.M.—Two specimens of zinc retort containing zinc spinel.

NORMAN, LADY.—Fourteen rocks collected in Discovery Bay during Capt. Scott's Expedition, 1910-1913, by Lieut.-Commander H. E. de P. Rennick, R.N.

POCOCK, LIEUT. R. W., R.G.A.—Ten igneous rocks from the Isle of Imbros.

REYNOLDS, PROF. S. H., SC.D.—Twenty-one specimens of igneous rocks, from Monmouthshire and Somerset.

ROBINSON & SON, MESSRS. J.—Samples of Blende from the Ladywash Mine, Eyam; Lump Fluor, Twelve Meres Mine, Eyam; Lump Barytes, Cupola Mine.

RUSSELL, F., ESQ. (THE GENERAL REFRACTORIES CO., LTD.).—Refractory materials.

SHERLOCK, DR. R. L.—A specimen of *Acentrophorus varians* (Kirkby) from the Magnesian Limestone of Fulwell, North-West of Sunderland.

SIDDONS, E. H., ESQ.—One specimen of Quartz-orthoclase porphyry from Axim beach, Pepreh Point, Gold Coast, West Africa.

SIMPSON, J. R., ESQ.—Six marine fossils from the Millstone Grit shales at Brockholes, near Huddersfield.

SMITH, H. G., ESQ.—Slide and specimen of Sapphire-bearing Lamprophyre, Lurgecombe Mill, Ashburton.

SMITH, JOHN, ESQ.—A micro-slide of Amber in Carboniferous Coal.

SNEYD COLLIERIES CO., LTD., MESSRS. THE.—Refractory materials.

TEALL, SIR J. J. H., F.R.S., ETC.—A specimen of Quartzite with supposed *Lingula*, from the Bunter Pebble Bed, near Birmingham.

TYRRELL, G. W., F.G.S.—Two micro-slides of Lugarite and Lamprophyre segregation, Old Quarry, Barshaw, near Paisley.

WADE, DR. A.—A series of Ordovician fossils from the Welshpool district, described in the *Quart. Journ. Geol. Soc.*, vol. lxvii, p. 415.

WHITEHEAD, CAPT. T. H., F.G.S.—Two specimens of igneous rock from the Isles of Imbros and Lemnos.

VII.—MAPS AND MEMOIRS, ETC., PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

ENGLAND AND WALES.

I.—MAPS.

SIX-INCH REFERENCE MAPS.

The following 67 standard copies of six-inch quarter-sheets have been made from the field-copies, and are available for reference:—

Bedfordshire, 32 S.W., 32 S.E. (Herts. 18 S.E.); 33 S.W. (Herts. 19 S.W.); 34 N.W. (Herts. 26 N.W.), 34 N.E. (Herts. 26 N.E.), 34 S.W. (Herts. 26 S.W.), 34 S.E. (Herts. 26 S.E.).

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Hertfordshire, 25 N.W., N.E., S.W., S.E.; 27 N.W. (Beds. 35 N.W.), 27 S.W.; 32 N.W., N.E., S.E.; 33 N.W., N.E., S.W., S.E.; 34 N.W., S.W.; 38 N.W., N.E.; 39 N.W.

Leicestershire, 42 N.E.; 43 N.W., N.E.; 43 S.W. (Warw. 12 S.W.), 43 S.E.; 48 N.E.

Warwickshire, 9 N.E., S.E.; 10 N.W., 10 N.E. (Leic. 41 N.E.), 10 S.W., S.E.; 11 N.W. (Leic. 42 N.W.), 11 S.W. (Leic. 42 S.W.), 11 S.E. (Leic. 42 S.E.); 15 N.E., S.E.; 16 N.W., N.E., S.W., S.E.; 17 N.W., N.E., S.W., S.E.; 18 N.W. (Leic. 48 N.W.), 18 S.W. (Leic. 48 S.W.), 18 S.E. (Leic. 48 S.E.); 20 N.E., S.E.; 21 N.W., N.E., S.W., S.E.; 22 N.W., N.E., S.W., S.E.; 23 N.W., 23 N.E. (Leic. 52 N.E.), 23 S.W., 23 S.E. (Leic. 52 S.E.; Northants. 21 S.E.).

II.—MEMOIRS.

Published Memoirs.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1915, pp. 55, text figures 3. Price 1*s*.

Special Reports on the Mineral Resources of Great Britain. Vol. I.—Tungsten and Manganese Ores. Second Edition. By H. Dewey and C. E. N. Bromehead, B.A.; with contributions by T. Eastwood, A.R.C.S.; G. V. Wilson, B.Sc.; and R. W. Pocock, B.Sc., pp. 59, text figures 2. Price 1*s*.

Special Reports on the Mineral Resources of Great Britain. Vol. II.—Barytes and Witherite. Second Edition. By R. G. Carruthers; T. Eastwood, A.R.C.S.; G. V. Wilson, B.Sc.; R. W. Pocock, B.Sc.; and D. A. Wray, B.Sc.; with contributions by H. Dewey and C. E. N. Bromehead, B.A., pp. 93, text figures 6. Price 2*s*.

Special Reports on the Mineral Resources of Great Britain. Vol. IV.—Fluorspar. By R. G. Carruthers; R. W. Pocock, B.Sc.; and D. A. Wray, B.Sc.; with contributions by H. Dewey and C. E. N. Bromehead, B.A., pp. 38, text figures 2. Price 9*d*.

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On the Thicknesses of Strata in the Counties of England and Wales exclusive of rocks older than the Permian. By A. Strahan, Sc.D., LL.D., F.R.S.; T. V. Holmes; H. Dewey; C. H. Cunnington, B.Sc.; W. C. Simmons, B.Sc.; W. B. R. King, B.A.; and D. A. Wray, B.Sc., pp. 172, text figures 36. Price 4*s*. 6*d*.

The Geology of the South Wales Coalfield. Part XII.—The Country around Milford (Explanation of Sheet 227). By T. C. Cantrill, B.Sc.; E. E. L. Dixon, B.Sc.; H. H. Thomas, M.A., Sc.D.; O. T. Jones, M.A., D.Sc., pp. 185, plates 7, text figures 30. Price 2*s*. 6*d*.

SCOTLAND.

I.—MAPS.

Six-inch Reference Maps.

The following copies of six-inch maps have been completed and deposited in the Office for reference:—

Argyll, 70 N.W., N.E.; 124; 149.

Elgin, 15.

Inverness, 26 N.W., N.E.; 56 N.E., S.E.; 72 N.E., S.W., S.E.; 86 N.E., S.E.; 101 N.E., S.E.; 102.

Nairn, 4; 7; 8.

Ross, 23, 27, 49, 53, 60, 74, 86, 98, 99, 118 N.W., N.E., S.W.; 119 N.E.; 120 N.W., N.E.

Sutherland, 41 N.W.; 51; 61.

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II.—MEMOIRS.

Published Memoirs.

Summary of Progress for 1915. See p. 28.

The Economic Geology of the Central Coalfield of Scotland. Description of Area V. (Glasgow East, Chryston, Glenboig and Airdrie). By C. T. Clough, M.A.; L. W. Hinxman, B.A., F.R.S.E.; W. B. Wright, B.A.; E. M. Anderson, M.A., B.Sc.; R. G. Carruthers; with contributions from R. Kidston, LL.D., F.R.S.; G. W. Lee, D.Sc., F.R.S.E., pp. 146, plates 13, text figures 5. Price 4*s.* 6*d.*

The Geology of Ben Nevis and Glen Coe and the surrounding Country (Explanation of Sheet 53). By E. B. Bailey, B.A.; and H. B. Maufe, M.A.; with contributions by C. T. Clough, M.A.; J. S. Grant Wilson; G. W. Grabham, M.A.; H. Kynaston, B.A.; W. B. Wright, B.A., pp. 247, plates 12, text figures 33. Price 7*s.* 6*d.*

Special Reports on the Mineral Resources of Great Britain. See p. 28.

APPENDIX I.

On a Deep Boring for Coal at Pollington, Yorkshire.

By W. Gibson, D.Sc.

Recent sinkings and borings around Doncaster have proved an extension of the Middle Coal Measures of the Yorkshire Coalfield eastward under the Permian and Triassic formations, south of an east-and-west line joining Askern (7 miles N.N.W. of Doncaster) and Thorne (12 miles N.E. of Doncaster). North of this line an area to the Ouse, at Selby, has been proved recently by some widely distributed borings, of which this one at Pollington (5 miles N.E. of Askern) is situated 8 miles east of the Visible Coalfield at Pontefract.

The Section (Abstract).

Boring for coal, one half a mile north-east of Heck Station, Yorkshire. Geological Map, Old Series, 87 N.E. 1 inch. New Series Ordnance Map, 79; 6 in. Yorks, 251 N.W. Lat. 53° 41′ 0″, Long. 1° 4′ 50″. Communicated by the North Yorkshire Boring Syndicate.

Height of surface above O.D. about 25 ft.

		Thickness. Ft.	In.	Depth. Ft.	In.
	Top soil...	8	–	8	–
Bunter (504 ft.)	Cemented sand (no core)	504	–	512	–
Upper Permian Marl (96 ft.)	Red and blue marl	51	6		
	Anhydrite	16	–	579	6
	Red marl and gypsum	27	–		
	Mottled marl	1	6	608	–
Upper Permian Limestone (90 ft.)	Limestone	10	–		
	Limestone with gypsum and shale ...	5	–		
	Grey shale	3	6		
	Limestone	7	6		
	Limestone with shale joints... ...	50	–		
	Limestone	8	6		
	Blue shale	1	6		
	Limestone	4	–	698	–
Middle Permian Marl (135¼ ft.)	Gypsum...	1	–		
	Blue shale and gypsum	5	–		
	Red marl, gypsum and anhydrite ...	125	–		
	Red anhydrite	4	6	833	

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		Thickness. Ft.	In.	Depth. Ft.	In.
Lower Permian Limestone (144½ ft.)	Limestone and gypsum	4	–		
	Limestone	140	6	978	–
Permian basal beds (15½ ft.)	Grey shale (*Lingula credneri*) ...	10	6		
	Grey sandstone	5	–	993	6
	Blue fireclay	2	6		
	Grey shale and ironstone bands ...	5	–		
	Grey shale and sandstone	12	–		
	Mottled marl	4	6		
	Grey shale and sandy shale	52	6		
	Grey shale and ironstone bands ...	6	6		
	Dark grey shale	4	6		
	Coal ... ... } Black shale ... } Coal... ... } [Shafton]	3 – 1	2 2 –	1,084	2
	Black shale and fireclay	1	6		
	Coal	1	2	1,088	–
	Fireclay...	3	–		
	Grey shale	12	6		
	Grey shale and sandy shale with two beds of fireclay	26	3		
	Sandy shale	9	–		
	Coal	2	4	1,141	1
	Fireclay	1	–		
	Sandy shale	46	5		
	Coal	1	6		
	Black shale	1	3		
	Shale and fireclay with ironstone nodules	11	3		
	Coal	1	–	1,203	6
	Fireclay...	2	3		
	Grey shale and ironstones	3	–		
	Coal	–	6	1,209	3
	Black shale and ironstone	1	8		
	Coal	–	7	1,211	6
	Fireclay...	1	6		
	Sandy shale	85	–		
	Dark shale	18	–		
	Coal	–	1	1,316	1
	Fireclay and shale	28	11		
	Shaly coal	5	9	1,350	9
	Fireclay...	5	9		
	Black shale with ironstone bands ...	31	–		
	Coal	–	2	1,387	8
	Fireclay, black shale with ironstones	40	10		
	Coal	1	11	1,430	5
	Fireclay, shale and sandstone ...	14	7		
	Shaly coal	–	3		
	Fireclays, shale, and sandy shale ...	148	3		
	Coal	1	–	1,594	6
	Fireclay...	5	6		
	Grey shale and sandy shale [sandstone ? Oak's Rock]	50	–		
	Coal	3	–	1,653	–
	Fireclay...	–	9		
	Shale and sandstone	29	6		
	Black shale	3	–		
	Coal	1	9	1,688	–
	Fireclay and shale	29	3		
	Coal	–	9	1,718	–
	Fireclay...	5	3		

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	Thickness. Ft.	In.	Depth. Ft.	In.
Grey sandstone... Shale with ironstone Grey sandstone... [? Wooley edge or Melton Rock.]	28	9		
	38	10		
	20	5	1,811	3
Shale with ironstone	19	6		
Coal	1	3	1,832	–
Dirt-parting	–	4		
Coal	1	11	1,834	3
Fireclay and shale	4	4		
Coal	–	5	1,839	–
Fireclay...	1	1		
Coal	–	8	1,840	9
Shale and ironstone	2	3		
Sandy shale and shale	40	–		
Coal	1	9	1,884	9
Shale and sandstone	21	9		
Shale and ironstone nodules... ...	15	6		
Coal	4	4	1,926	4
Fireclay and shale with ironstone ...	11	8	1,938	–
Coal	1	2	1,939	2
Dirt	1	–		
Coal	–	10		
Dirt	–	5		
Coal	–	1	1,941	6
Fireclay...	2	–		
Sandstone and sandy shale	16	9		
Shale and ironstone nodules ...	9	3		
Shaly coal	3	9	1,973	3
Fireclay...	2	3		
Shale and sandy shale, ironstone bands...	26	9		
Coal	–	2	2,002	5
Fireclay...	2	3		
Coal	3	–		
Fireclay...	1	2		
Coal	–	2		
Fireclay...	–	4		
Coal	–	2	2,009	6
Fireclay and ironstone balls ...	2	–		
Shale with fireclay and coal 2 in. at 2,026 ft.	15	2	2,026	8
Sandstone and sandy shale	13	1		
Shale	11	5		
Fireclay...	2	10		
Coal parting	–	3	2,054	3
Fireclay...	1	–		
Coal	1	–	2,056	3
Fireclay...	–	6		
Sandstone and shale	38	9		
Grey shale and ironstone bands ...	7	6		
Black shale [*Lingula*]	–	6		
Coal (cannel)	–	6	2,104	–
Black shale	1	6		
Shale with ironstone bands	14	3		
Coal	–	5	2,120	2
Fireclay...	18	4		
Sandy shale and sandstone	107	9		
Shale with ironstone, and sandy shale	78	3		
Coal	–	3	2,324	9
Fireclay...	2	–		
Shale	40	9		
Black shale	5	–		

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		Thickness. Ft.	In.	Depth. Ft.	In.
Coal		2	2	2,374	8
Fireclay		3	10		
Coal		–	4	2,378	10
Fireclay		4	2		
Sandstone and shale		19	6		
Coal		–	9	2,403	3
Fireclay		1	–		
Dark shale		2	6		
Coal		1	0	2,407	9
Fireclay		10	6		
Sandy shale and sandstone		37	9		
Black shale		1	–		
Coal		1	6	2,458	6
Fireclay		2	3		
Shale with ironstone bands		33	6		
Blue shale		1	9		
Coal	Warren House Coal.	–	9	2,496	9
Dirt		–	9		
Coal		–	7		
Dirt		–	9		
Coal		–	9		
Dirt		1	1		
Coal		2	–	2,502	8
Black shale and fireclay		2	10		
Coal		2	3	2,507	9
Fireclay		7	9		
Shale with ironstone nodules		29	–		
Coal		–	2	2,544	8
Fireclay		6	4		
Coal		–	3	2,551	3
Fireclay		1	3		
Sandstone and sandy shale		35	6		
Shale		11	–		
Coal	Dunsil.	3	–	2,602	–
Parting		–	6		
Coal		–	3		
Parting		–	5		
Coal		–	8	2,603	10
Fireclay		2	2		
Shale with ironstone nodules		66	6		
Coal		1	8	2,674	2
Black shale		1	–		
Sandstone and sandy shale		114	10		
Dark shale and ironstone		2	–		
Blue shale		3	–		
Coal	Haigh Moor or Glass Houghton Colliery.	–	6	2,795	6
Fireclay parting		3	–		
Coal		2	9	2,801	3
Fireclay		1	6		
Shales, fireclays, and streaks of coal		172	3		
Sandy shale		28	–	3,003	–

End of boring.

The boring was commenced with a diameter of 20 inches. The first 512 ft. through the Bunter Formation did not yield cores; but the Permian and Coal Measures produced good cores, which were 9 in. diameter at 1,593 ft. and 1,920 ft. and 6 in. diameter at 2,496 ft.—that is at those depths at which important coal horizons were entered.

The Permian strata proved to be similar in character to those at Carlton, Barlow and Selby (the Concealed Coalfield of York-

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shire and Nottinghamshire, *Mem. Geol. Surv.*, 1913). The total thickness is 481 ft. as compared with 565 ft. at Carlton, 610 ft. at Barlow, and 624 ft. at Selby, thus showing a steady northerly increment which is in agreement with that prevailing throughout the Concealed Yorks-Notts Coalfield. It is also known, by borings and sinkings, that the general inclination of the Trias and Permian formations is directed nearly due east, and at a rate per mile that brings the base of the Permian deposits to a depth approaching 3,000 ft. from the surface in the region bordering the Trent north of the Askern–Thorne line. Moreover, the rate at which the Permian basement bed slopes eastwards is so nearly uniform that, for this area, contours can be drawn showing its depths from the surface within extremely narrow limits of accuracy. Thus for all practical purposes the thickness and character of the cover to the Coal Measures can be estimated.

No appreciable dip of the Coal Measures could be determined, and since the deflection of the hole was shewn to be slight the thickness of 2,009 ft. proved in the boring may be taken as the true thickness.

The Upper Coal Measures are absent, and the boring ended in Middle Coal Measures about 350 ft. above the Silkstone Coal.

Numerous seams of coal were proved, but with the exception of that of the Warren House the names of the others have been added in square brackets to the section as supplied. There can be little doubt that the seam here taken as the Shafton is the same as the Shafton of Hemsworth Colliery, and the Nostell Seam of Nostell Colliery, and that the group of coals between 1,830–2,104 feet corresponds to that containing the Wathwood, Two-feet, Abdy and Stanley Main Coals of Yorkshire. This group of coals becomes of importance in the northern part of the coalfield, and analyses show that those at 1,834, 1,926, 2,007, 2,602 feet are of good quality.

That the Barnsley seam of the Doncaster region should have been found in the condition of the Warren House is in conformity with what occurs at Askern, and in the Visible Coalfield west of Pollington. The depth to the seam, however, is nearly 200 yds. greater than would have been the case if the low dip observable in the Visible Coalfield had continued eastward to the boring. It may be here remarked that at the Brodsworth Colliery the Barnsley Seam was found at a much shallower depth than was estimated from the dip observable in the nearest coal-workings to the west, nor are these the only cases in which estimated and proved depths have been found to differ in a marked degree. Probably it is safe to allow for a depth ranging between 2,500–3,000 ft. to the Barnsley Coal within the area north of the Askern–Thorne line.

[NOTE.—At the present stage of operations there are reasons against breaking up the cores systematically and investigating the fossil evidence. It may be stated that the characteristic marine band, between 600 and 750 ft. above the Barnsley Coal, and always easily detected in other borings and sinkings was not recognised, though a careful search was made between the depth of 1,700 and 1,950 feet.]

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APPENDIX II.

On Deep Borings for Coal and Ironstone at Bere Farm, Elham and Folkestone, Kent.

By J. Pringle, F.G.S.

The three borings described briefly below were made by the Channel Collieries Trust Ltd., and through the courtesy of Mr. E. O. Forster Brown the Geological Survey was invited to examine the cores, and is now permitted to make known the general results. Specimens were collected by the writer from the various formations passed through during the progress of the boring, and are still under investigation. Publication of full details must therefore be deferred, but it may be mentioned that the Upper Carboniferous rocks penetrated at Bere Farm and Folkestone correspond in their lithological characters to the Upper Series of Mr. H. Bolton's classification[1] of Kent Coal Measures, while the beds which overlie the Carboniferous Limestone at Elham undoubtedly belong to the Lower Series.

The Bere Farm Boring.

This borehole was situated in a field on the east side of the Dover–Deal road, about $1\frac{3}{4}$ miles north-east of Dover. In the year 1913 operations commenced in the Chalk at a height of 396 feet above O.D., and concluded in November, 1915, after reaching a depth of 3,005 feet. Considerable portions of the hole were punched through down to the base of the Gault, which was reached at a level 954 feet from the surface, and excepting that nearly the whole of the Oxford Clay was passed through by punching, a fairly continuous series of cores was made throughout the remaining portion of the section. The dip as judged by the cores is generally low, but on several levels varied between 15° and 25°. The limits assigned to the Chalk-Gault and Oxford Clay are based solely on information obtained from the log-book of the boring.

	Thickness. Ft.	In.	Depth. Ft.	In.
Clay	5	6	5	6
Chalk and Chloritic Marl	825	6	831	-
Gault Clay	123	-	954	-
Folkestone and Sandgate Beds (partly estimated) ...	62	-	1,016	-
Atherfield Clay	22	-	1,038	-
Weald Clay	35	-	1,073	-
Hastings Beds (partly estimated)...	7	-	1,080	-
Corallian Limestone...	1	-	1,081	-
Lower Corallian	79	-	1,160	-
Oxford Clay	80	-	1,240	-
Kellaways	23	-	1,263	-
Cornbrash	18	-	1,281	-
Forest Marble	10	-	1,291	-
Great Oolite	67	-	1,358	-

[1] H. Bolton. 'The Fauna and Stratigraphy of the Kent Coalfield.' *Trans. Inst. Mining Engineers*, 1915, vol. xlix, p. 643.

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		Thickness.		Depth.	
		Ft.	In.	Ft.	In.
Coal Measures (1,647 ft.)	Sandy shale and bind with a thin sandstone at top	92	–		
	Coal	–	10	1,450	10
	Hard black shale	4	6		
	Coal	–	10	1,456	2
	Hard black shale	78	–		
	Coal	–	3	1,534	5
	Hard black shale	55	–		
	Coal	–	10	1,590	3
	Hard black shale and hard grey sandstone	109	–		
	Coal	2	4	1,701	7
	Hard sandy shale and fireclay ...	65	–		
	Greyish-white quartzose sandstone, irregularly bedded and micaceous in places. Some pebbly courses...	94	5		
	Dark fireclay with stigmarian rootlets	7	–		
	Dark grey shales with *Neuropteris* ...	123	4		
	Coal	1	8	1,993	–
	Dark grey shales	27	–		
	Whitish-grey thin bedded micaceous sandstones with bands of dark grey shale	35	–		
	Dark grey and black shale with *Alethopteris* and *Neuropteris* ...	60	2		
	Coal	–	4	2,115	6
	Hard dark grey sandy shales with thin beds of whitish-grey sandstone near top	52	6		
	Hard grey sandstones with coaly films. Sandstones gritty at base, and contain numerous pebbles of coal and ironstone with *Neuropteris*	77	–		
	Grey shales, resembling fireclays in places, with numerous Stigmarian rootlets	64	6		
	Hard fine grained sandstone with coaly films	23	6		
	Dark grey and black shales with a bed of fireclay	27	–		
	Fine grained grey sandstone with a thin shale band	40	–		
	Dark brown fireclay with *Stigmaria*	7	–		
	Coal	–	3	2,407	3
	Dark brown fireclay passing below into dark micaceous shales with Stigmarian rootlets...	39	9		
	Hard grey sandstones with coaly films. Thin courses of conglomerate at 2,520 ft. and 2,541 ft. ...	100	–		
	Dark grey shales with thin micaceous sandstones	49	10		
	Coal	–	2	2,597	–
	Dark grey shales with a thin sandstone. Stigmarian rootlets abundant on many levels	193	–		
	Hard grey sandstone, micaceous in places	20	–		
	Dark grey shales and fireclay ...	12	–		

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		Thickness. Ft.	In.	Depth. Ft.	In.
Coal Measures (1,647 ft.)	Thin bedded dark grey micaceous sandstone passing below into hard grey quartzose sandstone with a 1 ft. band of conglomerate at 2,905 ft., containing pebbles of chert	86	–	2,908	–
	Dark grey shales with a thick bed of dark grey sandstone	38	6		
	Coal	–	10	2,947	4
	Dark grey fireclay with rootlets ...	2	8		
	Hard grey sandstones with thin pebbly courses at 2,980 ft. and 2,994 ft. containing pebbles of bright and dull coal	55	–	3,005	–

In the Cretaceous Group cores were available for the lower members only, and several had crumbled down, but sufficient details were secured to determine the existence of the sub-divisions mentioned. The only representatives of the Hastings Beds examined were some coarse sands which lay in pockets in the Corallian Limestone. From the Corallian Limestone to the base of the Great Oolite the sequence appeared to be complete, and all the formations yielded characteristic fossils, excepting the Oxford Clay, of which there were no cores. At the top of the Great Oolite the dip was 15°, but lower down it resumed the usual gentle angle. Lias was absent, and the Great Oolite rested directly on the Palæozoic floor.

A continuous series of cores was made in the Coal Measures, and all were available for inspection except some of the highest beds which were examined by Dr. E. A. N. Arber. The abundance of Stigmarian rootlets was notable in the argillaceous sediments, and many typical fossil plants were obtained, but no marine shells. The sandstones resembled those passed through at Folkestone, and there were also numerous courses of conglomerate with pebbles of coal, rolled fossiliferous ironstone-nodules, and fragments of dark chert.

The Elham Boring.

This borehole was situated in a field on the east side of the railway about 150 yards north-east of Elham station. Operations were commenced early in the year 1914 at a height of 275 feet above O.D., and ceased in June of the following year, after reaching the depth of 2,346 feet. Much of the boring was made by punching, but down from a depth of about 1,400 feet a nearly continuous series of cores was drawn. Above that level, in the absence of cores, thicknesses were estimated from the log-book.

	Thickness. Ft.	In.	Depth. Ft.	In.
Clay	3	–	3	–
Chalk and Chloritic Marl	287	–	290	–
Gault Clay	116	–	406	–
Folkestone, Sandgate and ? Hythe Beds	130	–	536	–
Atherfield Clay	30	–	566	–
Weald Clay	80	–	646	–
Hastings Beds	73	–	719	–
Kimmeridge Clay [partly estimated]	199	–	918	–
Upper Corallian	78	–	996	–

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		Thickness.		Depth.	
		Ft.	In.	Ft.	In.
Corallian Limestone [partly estimated]		129	–	1,125	–
Lower Corallian [partly estimated]		45	–	1,170	–
Oxford Clay		130	–	1,300	–
Kellaways, Cornbrash, and Forest Marble		68	–	1,368	–
Great Oolite, with ? Inferior Oolite at base [partly estimated]		131	–	1,499	–
Lias, including Upper, Middle, and Lower		99	–	1,598	–
Coal Measures (691 ft.)	Grey sandstones with thin bed of shale near base. *Sigillaria* ...	65	–		
	Dark grey micaceous sandy shales with thin beds of fireclay	91	–		
	Grey micaceous shaly sandstones with thin fireclay. Shales at base ...	68	–		
	Coal	1	8	1,823	8
	Dark grey shales with thin bed of fireclay, and thin-bedded micaceous sandstone. Stigmarian rootlets abundant	40	10		
	Coal	–	4		
	Fireclay	–	8		
	Coal	2	–	1,867	6
	Dark grey shales with Stigmarian rootlets	58	10		
	Coal	3	2	1,929	6
	Dark grey shales with 4 ft. band of muddy micaceous sandstone ...	21	10		
	Coal	2	8		
	Dark grey shales with Stigmarian rootlets	13	–		
	Coal	1	–	1,968	–
	Dark grey shales	11	–		
	Hard grey sandstones with partings of shale	21	–		
	Dark grey and blackish shales with lenticles of sandstone	13	–		
	Coal	1	4	2,014	4
	Dark grey sandy micaceous shale with thick beds of fireclay... ...	69	8		
	Dark grey sandstone with pebbles of shale. Bed of sandy micaceous shale near base	33	–		
	Dark grey shales	36	–		
	Coal	1	10	2,154	10
	Dark grey shales with thin bedded micaceous sandstone at top ...	12	2		
	Coal	1	6	2,168	6
	Dark grey shales with thin bed of fireclay	11	–		
	Coal	1	3		
	Thick bed of brownish-grey fireclay passing below into grey shales with lenticles of sandstone ...	25	3		
	Coal	1	5	2,207	5
	Dark grey sandy micaceous shales...	30	7		
	Black fine-grained bituminous limestone	3	–		
	Grey and black shales with thin bands of sandstone	40	–		
	Grey micaceous shaly sandstone with *Stigmaria* and an irregular lump of black chert (pebble?)	8	–	2,239	–
Carboniferous Limestone (57 ft.)	Dark grey bituminous limestone with thin beds of "china-stone." Corals and brachiopods abundant	57	–	2,346	–

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No specimens of the Cretaceous rocks were available, but particulars concerning the formations between the Hastings Beds and the Corallian Limestone, and also from a level in the Great Oolite Limestones down to the base of the Lias, were secured. A large series of characteristic fossils served to determine the horizons with precision. As at Folkestone, there was no observable discordance at the junction of the Mesozoic rocks with the Coal Measures; the bedding of the two appeared to be parallel.

The Coal Measures consisted mainly of dark shales with a few beds of grey sandstone, and contained several seams of coal. The shales yielded numerous plant-remains, and occasionally poorly preserved shells of lamellibranchs, but none of marine species. Near the base a 3-feet bed of black fine-grained limestone was passed through. It contained no fossils, but was underlain by grey and black shales with *Alethopteris* and Stigmarian rootlets. In the lowest beds of the measures there lay imbedded a large irregular lump of black chert, apparently derived from the Carboniferous Limestone. It is surrounded by a thick coating of iron pyrites.

The Carboniferous Limestone was represented by dark grey bituminous limestones with smooth fine-grained beds, or 'chinastones.' On several levels the rocks were highly fossiliferous, and contained numerous specimens of corals, poorly preserved owing to replacement by crystalline calcite. The fossils include: *Lithostrotion martini* (Edw. and Haime), *Syringopora sp.*, *Chonetes sp.* [papilionaceous form], *Productus* cf. *corrugatus* (McCoy), *Productus sp.*, *Spirifer sp.*, and several indeterminable species of gasteropods. The rocks are of Visean age, and probably represent the upper part of the Seminula Beds or the lower part of the Dibunophyllum Zone.

The Folkestone Boring.

This borehole was situated in a disused brickyard near the southernmost Martello tower overlooking East Wear Bay. Towards the end of the year 1915 boring commenced in Gault Clay at a height of about 113 feet above O.D., and ceased in December, 1916, after reaching a depth of 3,400½ feet. The dip of the Coal Measures varied from 5° to 15°. Much of the boring was punched, and the thickness of the Cretaceous and Jurassic rocks above the Lias could only be estimated by help of the notes in the log-book.

	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Gault Clay	85	–	85	–
Folkestone, Sandgate and ? Hythe Beds	210	–	295	–
Atherfield Clay	40	–	335	–
Weald Clay	165	–	500	–
Hastings Beds	53	–	553	–
Kimmeridge Clay [partly estimated]	210	–	763	–
Upper Corallian	123	–	886	–
Corallian Limestone [partly estimated]	123	–	1,009	–
Lower Corallian	81	–	1,090	–
Oxford Clay	172	–	1,262	–
Kellaways, Cornbrash, and Forest Marble	38	–	1,300	–
Great Oolite with ? Inferior Oolite at base	75	–	1,375	–
Lias	112	–	1,487	–

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		Thickness. Ft.	In.	Depth. Ft.	In.
Coal Measures 1,913¼ ft.	Grey sandy micaceous shales and binds, with a thick dark grey shaly sandstone at base. *Sigillaria* ...	27	–		
	Hard grey quartzose sandstone with thin gritty and pebbly bands. Numerous large rounded pebbles of coal	30	–		
	Dark grey shales with a thick bed of grey shaly micaceous sandstone. *Neuropteris* and *Calamites* abundant	91	6		
	Coal	–	3	1,635	9
	Dark grey shales with a thick bed of grey sandstone with shaly partings	38	9		
	Coal	2	–	1,676	6
	Dark grey and black shales with ironstone nodules. *Alethopteris* ...	49	6		
	Coal	1	2	1,727	2
	Hard grey shaly sandstone with carbonaceous films	18	10		
	Grey sandy shales with thin shaly sandstones. Lamellibranchs ...	142	–		
	Fine grained dark grey shaly sandstone	46	–		
	Grey sandy shales with thin grey sandstones	102	–		
	Coal	–	7	2,036	7
	Smooth grey sandy shales	36	5		
	Coal	–	8	2,073	8
	Grey sandy shales with thin sandstones	37	4		
	Grey gritty quartzose sandstone. Between 2,122 ft. and 2,129 ft., and and at 2,150 ft. sandstone contains numerous pebbles of coal and shale	42	6		
	Lumpy greenish-grey shales, red in places, with sandy micaceous bands	86	6		
	Grey sandy shales with a thick bed of shaly sandstone. *Neuropteris* and lamellibranchs common ..,	51	–	2,291	–
	Hard fine-grained grey sandstone passing down into hard grey quartzose sandstones with 6-in. courses of conglomerate at 2,420 ft. and 2,426 ft. Pebbles of quartz, chert, shale, &c.	182	–		
	Grey sandy shales and a thin bed of fireclay	13	–		
	Coal	1	2	2,487	2
	Dark grey shaly sandstone, passing below into a hard whitish-grey speckly sandstone with three thin bands of grey sandy shales ...	146	10		
	Dark grey and black shales. *Neuropteris*	24	–		
	Hard dark grey sandstone with coaly films	92	–		
	Dark bluish-grey and grey shales with two thick bands of shaly sandstone	76	–		
	Hard grey fine-grained sandstone ...	43	–		
	Grey and black shales	168	–		

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		Thickness. Ft.	In.	Depth. Ft.	In.
Coal Measures 1,913½ ft.	Hard grey fine-grained sandstone ...	58	–		
	Dark grey shales	7	–		
	Coarse grey gritty sandstone passing below into fine-grained grey sandstone. Brownish-grey fireclay at base	16	–		
	Hard grey gritty sandstones. Pebbles of coal at 3,180 ft.	172	–		
	Dark grey shales and thin beds of fireclay with a 12-ft. band of grey sandstone	110	6	3,400	6

For the reason stated we were not able to examine the strata between the Gault Clay and the lower part of the Kimmeridge Clay, or those between the Corallian Limestone and the Lias. Such cores as there were, however, of the Jurassic rocks yielded characteristic suites of fossils. There was no obvious discordance at the junction between the Mesozoic and Palæozoic rocks; the Lower Lias rested on a smooth irregular surface of the Coal Measures.

A continuous series of cores was available in the Coal Measures. The grey shales yielded plant-remains, and on several levels lamellibranchs were abundant, but no marine forms were found. The thick group of shales which were passed through between the depths of 2,153½ feet and 2,240 feet are noticeable on account of the presence of thin mottled red bands at two levels. When wet, the beds were generally of an olive-green hue, and they broke into lumps with a marly cuboidal fracture. Similar rocks do not appear to have been recorded hitherto in the Coal Measures of Kent. Thick beds of hard grey quartzose sandstone formed a characteristic feature in the cores, and several of them contained courses of conglomerate loaded with pebbles or subangular fragments of hard bright coal. Thin bands of conglomerate also occurred in a group of sandstones at 2,420 feet and 2,426 feet from the surface, and yielded pebbles of quartz, black shale, chert, and jasper. Microscope-sections of the chert show abundant remains of Foraminifera.

APPENDIX III.

On a Deep Boring made in 1907-9 at Battle.

By G. W. Lamplugh, F.R.S.

This boring was briefly referred to in the 'Summary of Progress for 1910,' p. 63, and a short abstract of the section was given in the 'Water Supply of Sussex (Supplement),' p. 243 (1911, *Mem. Geol. Surv.*), but the particulars have not hitherto been published.

The boring was carried out in 1907–1909 for the South-eastern Development Syndicate, Ltd., to whom we are indebted for access to the cores and journal. The site is 1,650 yds. N.N.E. of Battle Church, in a field at the S.W. side of Petley Wood

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(6-inch Ordnance Map, Sussex, 43 S.E.; 1-inch New Series, Sheet 320), at a height of about 120 ft. above O.D. The boring reached a depth of 2,066 ft. from the surface; it is $2\frac{3}{4}$ miles E.S.E of the old 'Sub-Wealden borings'[1], one of which attained a depth of 1,905 ft.; but a fault (shown on the Geological Survey Map, Old Series, Sheet 5), with a south-westerly downthrow, runs between the two sites and brings in at least 600 ft. of higher strata at the new boring. Therefore, although the last boring was the deeper of the two, the Sub-Wealden boring reached nearly 500 ft. lower in the stratigraphical sequence.

The cores of the recent boring ranged in diameter from $8\frac{1}{2}$ inches near the top of the section to 3 inches at the bottom, and were practically continuous. When examined by us in 1909 most of them had been exposed to the weather, with the result that the softer clays and shales had crumbled badly, and only the bands of firmer rock had remained intact. Therefore only a comparatively incomplete set of the fossils was obtainable; but there was not much difficulty in determining the composition and sequence of the strata.

The following section has been based mainly on this personal examination of the cores; some of the details, however, have been abstracted from the journal of the boring.

Section of Wealden and Upper Jurassic Rocks at Battle.

			Thickness.	Depth.
			Ft.	Ft.
Wealden: (Hastings Beds), 424 ft.	Ashdown Sand, 184 ft.	Soil	2	
		Weathered clay with sandstone, and blue sandy clay	14	
		Soft pale sandstone	13	
		Dark and light marly clay	23	
		Pale sandstone	15	
		Marly clay with 4-ft. band of sandstone and 7-in. hard band	37	104
		Pale sand and sandstone with a gravelly band and some marly beds	80	184
	Fairlight Clays, 240 ft.	Pale sandy clay	35	
		Pale and dark grey shaly sandstone, with bands full of plant-remains	41	
		Red and variegated marly clay and pale clay	9	
		Alternations of shaly sandstone and sandy clay, with some bands of fresh-water shells (*Cyrena*; *Viviparus*, etc.)	76	
		Grey or bluish sandstone, mostly shaly	79[2]	424

[1] Several accounts of these borings have been published; *see* H. B. Woodward, 'Jurassic Rocks of Britain,' vol. v., *Mem. Geol. Surv.*, 1895, pp. 345–7; and W. Whitaker, 'Water Supply of Sussex,' *ibid.*, 1899, pp. 55–70.

[2] In the summary of the section previously published ('Water Supply of Sussex (Supplement),' p. 244), the base of the Hastings beds was taken at 345 ft., the 79 ft. of shaly sandstone being reckoned as part of the Purbeck beds. The amended classification here proposed brings the section into closer correspondence with the method of division for the beds at outcrop adopted in the memoir 'The Geology of the Weald.' There is, however, no sharp line of division between the Wealden and the Purbeck beds.

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		Thickness. Ft.	Depth. Ft.
Purbeck beds, 387 ft.	Dark grey and greenish marly clay with bands of sandy shale and pale sandstone	35	
	Grey marly clay with bands and nodules of limestone	16	
	Alternations of dark silty shale, sandy shale and clayey shale, and greenish clays, with bands and nodules of ironstone, pale layers crowded with white fresh-water shells, *Cyrena media* (J. de C. Sow.), etc., and thin impure limestone... ... ... about	135	610
	Dark hard calcareous shale with some bands of marine or estuarine shells, including *Ostrea distorta* J. de C. Sow., *Corbula* cf. *inflexa* Sandb., *Protocardia?* etc. ... ... about	15	625
	Alternations of dark calcareous clay and clay-stone, sandy shale and impure sandstone, greenish marly clays and thin bands of clayey limestone ... ... about	139	764
	Gypsiferous beds. Calcareous shale and flaggy claystone veined and banded with gypsum ...	15	
	Impure gypsum with shaly partings ...	12	
	Gypsum with thin shaly bands	6	
	Hard yellowish gypsiferous cement-stone with irregular lumps and veins of white gypsum	14	811
Portlandian, 141 ft.	Yellowish-grey soft dirty sandstone, massive in structure, with obscure dark casts of fossils and wispy markings like fucoids; in the lower half, some harder slightly calcareous bands containing better preserved fossils; strong bituminous odour in some of the softer beds. *Trigonia gibbosa* J. Sow., *T.* cf. *incurva* Benett, etc.	71	882
	Darker muddy sandrock or sandstone with hard calcareous bands, and intercalations of sandy shale with clay-stone nodules; strong bituminous odour prevalent; the shales become predominant downward and form an insensible passage into the Kimmeridge clay. '*Holcostephanus*' *sp.* [fragment], *Ostrea* cf. *bononiae* Sauv., *Perna sp.*, *Rhynchonella sp.* ...	70	952
Kimmeridge Clay, 1,114 ft. proved.	Upper Kimmeridge. Dark clay-shale, more or less marly, with some beds of 'papery' shale full of crushed fossils, and a few thin bands of hard splintery claystone. Cores much weathered. *Lingula ovalis* J. Sow., *Orbiculoidea latissima* (J. Sow.), *Protocardia morinica* (de Lor.), *Modiola autissiodorensis* (Cott.), *Aporrhais* cf. *piettei* (Buvign.) *Astarte spp.*, *Pinna sp.*	247	1,199
	Indurated marly clays with few fossils, and hard splintery claystones veined in places with calcite, alternating with thick bands of shaly clay full of fossils, and with some thin bands of platy bituminous shale. Fossils, same as last; also *Harpagodes sp.*, *Corbula sp.*, etc.	232	1,431

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			Thickness. Ft.	Depth. Ft.
Kimmeridge Clay, 1,114 ft. proved.	Virgula beds.	Dark muddy sandstone, mottled with carbonaceous matter, merging in places into sandy shale with lumpy and crumpled bedding. *Exogyra virgula* (Defr.)	41	1,472
		Marly clays with shelly layers. *Exogyra virgula* (Defr.)	57	1,529
		Palish-grey and mottled muddy sandstones and sandy shales, in parts calcareous. *Exogyra virgula* (Defr.), *Gervillia kimmeridgensis* (d'Orb.) ...	54	1,583
		Marly and shaly clays, with a few hard calcareous bands; few fossils obtainable as most of the cores were crumbled by weathering. *Exogyra virgula* (Defr.), *Astarte sp.*, *Pecten* (*Camptonectes*) *sp.*, *Pleuromya sp.*, fragments of ammonites	137	1,720
		Dirty grey sandstones and sandy shales, with occasional intercalations of clay-shale; some of the sandy beds calcareous and hard, others semi-coherent sand-rock, mottled with tubular markings (? due to boring organisms); the fossils include casts of large bivalves in the upright position of life	50	1,770
		Marly and shaly clays with a little sandy shale; cores nearly all crumbled. *Exogyra virgula* (Defr.), *Anomia* cf. *suprajurensis* Buvign., fragments of ammonites...	169	1,939
		Fine-grained sandy limestone and clayey calcareous sandstone, banded with shale; good cores. *Exogyra virgula*? (Defr.)	8	1,947
		Calcareous shales, slightly sandy in places, banded and intermingled with hard clayey limestone and nodular cement-stone; good cores. *Exogyra virgula*? (Defr.), *Pinna granulata* J. Sow., *Pholadidea* cf. *compressa* (J. de C. Sow.), *Pleuromya sp.*, *Lingula ovalis* J. Sow., *Rhynchonella sp.*, *Terebratula sp.*, *Serpula sp.*, *Cidaris* (spine), '*Holcostephanus*' aff. *stephanoides* (Oppel)	119	2,066
		Bored, but core not drawn	5	2,071

The bottom beds are probably close to the base of the Kimmeridgian series, if not actually within the Upper Corallian.

The particular interest of this boring is in the means it affords for comparing the Upper Jurassic sequence on the southern side of the Wealden dome with that which was proved by the boring at Penshurst, near Tonbridge, on the northern side.[1]

Both borings began not far below the top of the Ashdown Sand, and both, after passing through the entire Purbeck and Portland series, terminated in Kimmeridge Clay. But while the Battle boring reached nearly, if not quite to the base of the Kimmeridge series, the Penshurst boring stopped before reach-

[1] 'On the Mesozoic Rocks in some of the Coal Explorations in Kent.' *Mem. Geol. Surv.*, 1911, pp. 66–77.

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ing the Virgula Beds which form the lower and larger part of the Kimmeridge Clay. A comparison of the thickness of the formations proved at the two places is shown in the following table:—

	Battle, 120 ft., O.D.		*Penhurst*, 85 ft., O.D.	
	Thick-ness.	Depth.	Thick-ness.	Depth.
	Ft.	Ft.	Ft.	Ft.
Wealden, from near top of Ashdown Sand	424	424	552	552
Purbeck beds	387	811	562	1,114
Portland beds	141	952	131	1,245
Upper Kimmeridge Clay...	479	1,431	622	1,867
Lower Kimmeridge Clay...	635	2,066		

. In respect to the Wealden beds, the comparison may not carry much weight, as this series is variable and merges insensibly downward into the Purbeck beds. But the base of the Purbeck is a sharp boundary, and the Virgula beds of the Kimmeridge Clay are also definite. It is certain, therefore, that the Upper Jurassic formations in the aggregate are thinner at Battle than at Penshurst by at least 300 ft., and that these rocks on the southern side of the dome sink northward towards Penshurst. This structure is complementary to that on the northern side of the dome where, as the borings in Kent have proved, there is a great southward thickening of the same rocks and of the deeper Jurassic formations accompanied by a southerly dip.[1] As was pointed out in the memoir above cited, the effect of this structure is that the Wealden anticline of the Cretaceous rocks is superimposed upon a buried syncline of the Jurassic rocks. The present boring yields confirmatory evidence for the buried syncline.

The average northerly inclination of the Jurassic planes of division between Battle and Penshurst indicated by the table is locally reduced by the previously-mentioned fault; if the levels of the same planes in the old Sub-Wealden borings on the upthrow side of the fault be taken for the comparison, the dip becomes accentuated.

The position of the deepest part of the buried syncline has not yet been proved; it probably lies nearer Penshurst than Battle.

If compared with the records of the same formations in the Sub-Wealden borings, the present record will be found to differ in many points of lithological detail. These discrepancies may arise mainly from the doubtful determination of some points in the Sub-Wealden section as compiled from various separate records.

[1] See pp. 45-52 of present 'Summary'; also previous memoir 'On the Mesozoic Rocks, etc., in Kent,' *supra cit.*

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APPENDIX IV.

The Underground Range of the Jurassic and Lower Cretaceous Rocks in East Kent.

By G. W. Lamplugh, F.R.S.

Since the publication of the Geological Survey Memoir on 'The Mesozoic Rocks in some of the Coal Explorations in Kent' in 1911, the officers of the Survey[1] have had opportunities[2] for examining the cores of the Mesozoic rocks from most of the numerous borings which have been made in Kent. A summary of the information obtained may now be given.

Almost all the new borings lie farther north than those previously described, and are therefore in the region where the sequence of Mesozoic rocks is shorter and less nearly complete than in the Brabourne and Dover sections already dealt with. They are sufficiently numerous to bring out clearly the underground range of the various formations proved in the older borings, and incidentally to confirm the deductions as to the underground structure which were stated in the memoir referred to. The unexpected fact that in this district the Palæozoic floor is reached at a less depth beneath the highest outcropping formation (Eocene) than beneath the lowest (Wealden) is explained mainly by the disappearance northward of all the Oolitic formations in turn, under the Cretaceous unconformity, and the similar disappearance of the Lias under the unconformity of the Oolites. As a result of the borings we are able to fix the position of the ancient outcrops of the formations beneath the unconformities and approximately to trace their hidden boundaries. This information is likely to be of practical service where mining operations are contemplated.

The structure of the concealed Jurassic rocks in this area proves to be comparatively simple. If all the Tertiary and Cretaceous formations could be stripped off from the country south of the Stour valley (and the sea excluded) a broad smooth slope would be laid bare, descending nearly north-eastward from the Folkestone–Ashford area to the tract under the present Stour at a rate diminishing from about 40 feet per mile in the south to 20 ft. or less in the north; and across this slope the outcrops of the successive formations from the Great Oolite upward to the Portlandian would be found to stretch in parallel belts striking, with slight irregularity, west-north-westward from the line of the present coast. The Lias would still remain hidden by the unconformable overlap of the Lower Oolites; but its course is nearly, though not quite, parallel to that of the other Jurassic formations. The strike of these belts is nearly the same as that of the Cretaceous rocks now seen at the surface, but

[1] The material from the borings has been examined at the sites by the writer and Mr. J. Pringle, the fossils have been determined in the Palæontological Department of the Survey by Dr. F. L. Kitchin and Mr. J. Pringle.

[2] We are particularly indebted to Dr. Malcolm Burr and to Mr. E. O. Forster Brown for access to the many borings respectively under their charge.

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their dip, though slight, is diametrically different, being southerly instead of northerly, so that if they were at the surface their escarpments would face in the opposite direction to that of the Chalk.

The relative underground positions and approximate boundaries of the Jurassic belts in north-east Kent are shown diagrammatically in Fig 2; and the structure, down to the Palæozoic floor, is illustrated by the section forming Fig. 3.

The salient characters and stratigraphical relations of the several formations, in ascending sequence, are as follows.

Lias.—The northward limit of the Lias is nearly coincident with the main railway-line between Canterbury and Dover, and the formation has been proved in all the East Kent borings south-west of that line. Its thickness diminishes steadily from 140 ft. in the south-west (Brabourne) to less than 15 ft. near its northern margin, partly through the thinning of its individual members and partly through the shaving down of its top before the deposition of the Lower Oolites. But even in some of the borings where thinnest (Fredville, 13½ ft.; Bishopsbourne, 22 ft.; Chilton, 25ft.), the presence of beds belonging to the three major subdivisions, Upper, Middle, and Lower Lias, has been proved by the evidence of fossils.

The Upper Lias consists mainly of smooth clay-shale; the Middle Lias, of alternations of shale, hard shelly limestone and calcareous sandstone, occasionally rather ferruginous; the Lower Lias, mainly of clay-shale and sandy-shale with a few thin limestone-bands. The occurrence of a conglomeratic band in the Middle Lias at Chilton suggests the neighbourhood of a shore to the northward, and it is probable that the Palæozoic rocks were above sea-level during part of the Liassic period in the north-eastern corner of the area shown in Fig. 2.

The Trias, proved in the older boring at Brabourne,[1] is absent from all the borings examined to the northward and eastward; and the Lias wherever present in the newer borings is found to rest directly upon a freshly-eroded and unweathered surface either of the Coal Measures or still older rocks.

Lower Oolites.—The Lower Oolites are the last portion of the Jurassic sequence to be cut out northward by the Lower Cretaceous unconformity, and they therefore occupy a larger area underground in East Kent than any other division of the Jurassic system. In the west, their northward termination probably lies well within the Tertiary area, about 3 miles north of Canterbury, but, striking east-south-east, leaves this area before Sandwich is reached, and curves south-eastward into the Chalk country a mile or two west of Deal, evidently controlled by the shape of the rising Palæozoic platform.

In the borings nearest this northern margin the Lower Oolites appear to range from about 20 ft. to about 40 ft. in thickness, and to consist mainly of the Great Oolite limestone; but the method of boring has yielded only imperfect evidence. Southward and westward from the margin the division increases steadily in thickness, until at Brabourne, in the

[1] *See* 'Mesozoic Rocks in some of the Coal Explorations in Kent.' *Mem. Geol. Surv.*, 1911, pp. 51–54.

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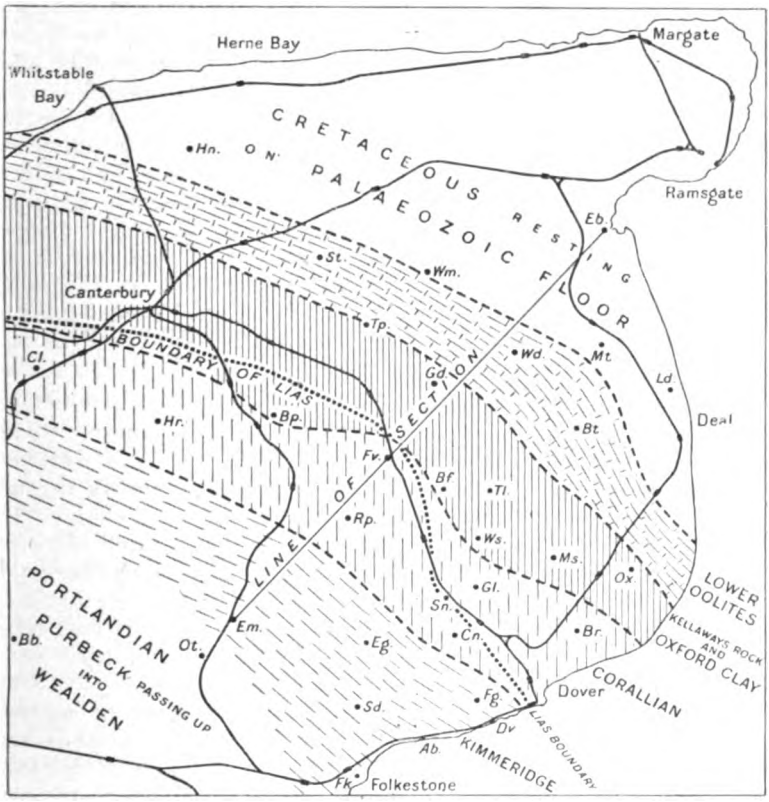
Fig. 2.—Sketch-map showing range of buried Jurassic formations in East Kent.



Scale of Miles

0 5 10 15

Railways, with position of stations, shown by continuous black lines.

Borings (and shafts) from which information has been obtained, indicated by black dots, lettered as follows:—

Ab., Abbotscliff.
Bb., Brabourne.
Bf., Barfreston.
Bp., Bishopsbourne.
Br., Bere Farm.
Bt., Betteshanger.
Cl., Chilham.
Cn., Chilton.
Dv., Dover (shafts).
Eb., Ebbsfleet.
Eg., Ellinge.
Em., Elham.
Fg., Farthingloe.
Fk., Folkestone.
Fv., Fredville.
Gd., Goodnestone.
Gl., Guildford (shaft)
Hn., Herne.
Hr., Harmansole.
Ld., Lydden Valley.
Ms., Maydensole.
Mt., Mattice Hill.
Ot., Ottinge.
Ox., Oxney.
Rp., Ropersole.
Sd., Lower Standen.
Sn., Stone Hall.
St., Stodmarsh.
Tl., Tilmanstone (shafts).
Tp., Trapham.
Wd., Woodnesborough.
Wm., Walmestone.
Ws., Waldershare.

south-western corner of the area, it measures 194 ft. The belt in which the Lower Oolites form the floor immediately beneath the unconformable Cretaceous rocks has an average width of about 2 miles, but becomes narrower before reaching the present coast-line between Deal and St. Margaret's Bay (see Fig. 2).

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Stratigraphically and palæontologically, the development of the Lower Oolites in East Kent is similar to that in the South-west of England, and is unlike that in the East Midlands and Lincolnshire. In all borings where the full sequence was represented by adequate cores, it was possible to recognise the main subdivisions present in the South-west of England, from the Cornbrash downward to the bottom of the Great Oolite series; but the Inferior Oolite was identified in a few places only, and appears to be often absent and nowhere complete. The following are the subdivisions determined in the borings, with the range of their thickness, in round numbers, where not affected by the Cretaceous unconformity.

	Ft.
Cornbrash	10 to 20
Forest Marble	10 to 20
Great Oolite limestones	40 to 120
Great Oolite sandy beds, with part of Inferior Oolite in places	0 to 40

The bottom sandy beds are thickest and best marked in the borings farthest east; they thin out northward, while westward and south-westward they tend to lose their individuality through the intercalation of sandy limestones and bands of shale. The sands generally contain large calcareous 'doggers' and are often mottled with fragments of lignite; they pass unconformably across the Lias to the bare Palæozoic platform which must have suffered renewed erosion in the northern area during their deposition. They represent the scourings from adjacent land, swept off-shore and deposited in shallow-water.

The Great Oolite limestone is the most conspicuous member of the Lower Oolites, and also the most variable in thickness, so that most of the south-westward increase of the Lower Oolites is due to the swelling of these limestones. Its main beds are composed of pale massive oolite, usually of medium or close grain, and poor in fossils; but toward the north and east these become attenuated and split up by partings of clay-shale and oolitic rubble in which fossils are often abundant. The close-grained rock, if accessible, should make an excellent building-stone, a point worth mentioning in view of the fact that mining shafts have already been sunk through it and that more are in prospect.

The Forest Marble series and the Cornbrash are relatively minor subdivisions, and show comparatively little change in thickness within the area, being, if anything, slightly thicker in the north-eastern part of their range than elsewhere. Both are heterogeneous deposits, chiefly of marl and clay with irregular bands of limestone, calcareous sandstone and oolitic rubble. They are distinguishable mainly by their fossils, which are numerous, and by the presence of green clay and a peculiarly compact limestone in the Forest Marble.

Kellaways Rock and Oxford Clay.—Where pierced in the Kentish borings, the Kellaways Rock is readily identifiable by its composition and fossils, though there is sometimes difficulty in determining precisely its upper and lower limits. Its underground contact with the overlapping Cretaceous strata occurs in a narrow belt running E.S.E. from the neighbourhood of Canterbury to the coast near St. Margaret's. This belt is not wide enough to be shown separately in Fig. 2, and it is therefore

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united with the broader belt of the overlying Oxford Clay, the two together having a breadth ranging from about 1½ mile in east to about 3 miles in the west.

The Kellaways Rock appears to attain its greatest thickness about midway between Canterbury and the coast, 43 ft. being assigned to it in the Fredville boring, whereas farther east it drops to between 30 and 37 ft., and farther west to under 20 ft. (Brabourne and Harmansole). The differences may be in part due to the uncertainty as to its boundaries, but seem also to indicate some interchangeability of composition with the lower portion of the Oxford Clay, as in other parts of the country. In its lithological aspect, the Kellaways Rock shows much local variability; in the more southerly and south-easterly sections its chief component is an impure marly sandstone with some ferruginous beds, but inland and northward the main portion is a ferruginous marlstone, sometimes highly glauconitic. Much of the iron in this ferruginous rock is disseminated in round coffee-coloured 'millet-seed' grains; and it therein resembles the Upper Corallian iron-ore, though stated to be less rich in iron and to contain a larger proportion of deleterious matter. Its possible commercial value, however, deserves attention. In some of the borings, particularly Fredville, parts of the rock are so rich in glauconite as to be quite green in colour.

The Oxford Clay is the least variable of all the Kentish Jurassic deposits; wherever seen, it has consisted almost wholly of fine-textured marly clay without conspicuous bedding, and mostly of a palish grey-blue tint with some subordinate brown bands. It thickens rather rapidly westward from 88 ft. at Dover to 173 ft. at Brabourne, and about the same at Chilham, with intermediate values at points between these places.

Corallian Series.—The Corallian rocks have a strong development in the southern part of East Kent, their range including nearly all the tract south-west of the main road (Watling Street) between Dover and Canterbury. The thickness of the whole series, as ascertained in the Dover shafts, is 310 ft., and in the Brabourne boring 342 ft., so that the westerly expansion is not so marked as in most of the Jurassic formations. The beds probably become thinner northward, but owing to the incomplete state of the series in this quarter, comparison is difficult. The northern edge of the formation lies a mile or two south of Canterbury, and runs E.S.E. to the coast between Dover and St. Margaret's. This boundary appears to have a pronounced southward bulge near Bishopsbourne and a northward bulge between Fredville and Barfreston (see Fig. 2). These bends may denote faulting, or they may indicate that the thick limestones of the series have an irregular escarpment buried under the Wealden deposits. The average width of the Corallian belt beneath these deposits is about 3 miles.

The most characteristic and persistent portion of the Kentish Corallian series is the thick mass of pale coralline limestones which forms the middle part of the formation and has, in the south, a thickness of 125–135 ft. Both above and below these limestones the series consists mainly of clays, marls, marlstones and rubbly oolites with subordinate bands of impure limestone. In these beds there is frequently an admixture of ferruginous matter in the form of small coffee-coloured granules of iron-

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oxide, which are in places segregated into bands of iron-ore like that of Westbury, in Wiltshire. The thickest of these bands occurs in the Dover district in the beds above the coralline limestones, and is likely to prove of economic value.

The separation of the Corallian from the Oxford Clay below and the Kimmeridge Clay above is largely dependent upon palæontological evidence. Fortunately, fossils are sufficiently abundant to define the boundaries within narrow limits.

Kimmeridge Clay.—The few additional borings which have pierced the Kimmeridge Clay have yielded hardly any material for examination. Fortunately the explorations previously described[1] gave full opportunity for the study of this formation, while the recent borings have sufficed to fix its underground range fairly closely (see Fig. 2).

Attention may here be called to the description on p. 40 of a deep boring near Battle, in Sussex, in which the Kimmeridge Clay was fully displayed, and the Portland and Purbeck beds also.

Portland and Purbeck Beds.—None of the Kentish borings recently examined lie within the range of these rocks.

Lower Cretaceous—Wealden and Lower Greensand.—Lower Cretaceous strata were passed through in all the borings examined with the doubtful exception of that near Herne; but cores were available in only a few instances. Fortunately several of the beds can be identified even from small chiselled chips; in particular, the glauconitic rock-band just below the Gault; the chocolate-brown bed in the Atherfield Clay; the cyprid-shales of the Weald Clay; and the sharp quartz-sands at the base of the Wealden.

The Wealden beds stretch well beyond the area covered by the Jurassic rocks in East Kent. In this quarter they probably continue nearly as far northward as the Lower Greensand, and the two appear to be practically conformable, though the Lower Greensand is known to overlap the Wealden beds in the north-western part of the county. Both formations are present at Ebbsfleet, and both are believed to be absent in the neighbourhood of Herne; but the evidence in this northern tract is as yet insufficient to define the boundaries of either formation. It is certain, however, that their strike is not quite the same as that of the Jurassic rocks or of the Gault.

The thickness of the Wealden series in the Ebbsfleet boring is only 15 ft., but it increases steadily southward to 85 ft. at Dover, and appears not to exceed this in any of the borings between Dover and Canterbury, with one doubtful exception (Chilton). To the south-westward of this belt the expansion must be more rapid, as the Brabourne boring proved 309 ft. of Wealden deposits. Even where thinnest, the series shows a change of character from sandy and silty beds in the lower portion to clayey and shaly beds in the upper portion; but these thin subdivisions can hardly be regarded as strictly equivalent to the thick masses of Weald Clay and Hastings beds that are seen in the Weald in similar relationship.

[1] 'Mesozoic Rocks,' *op. supra cit.*

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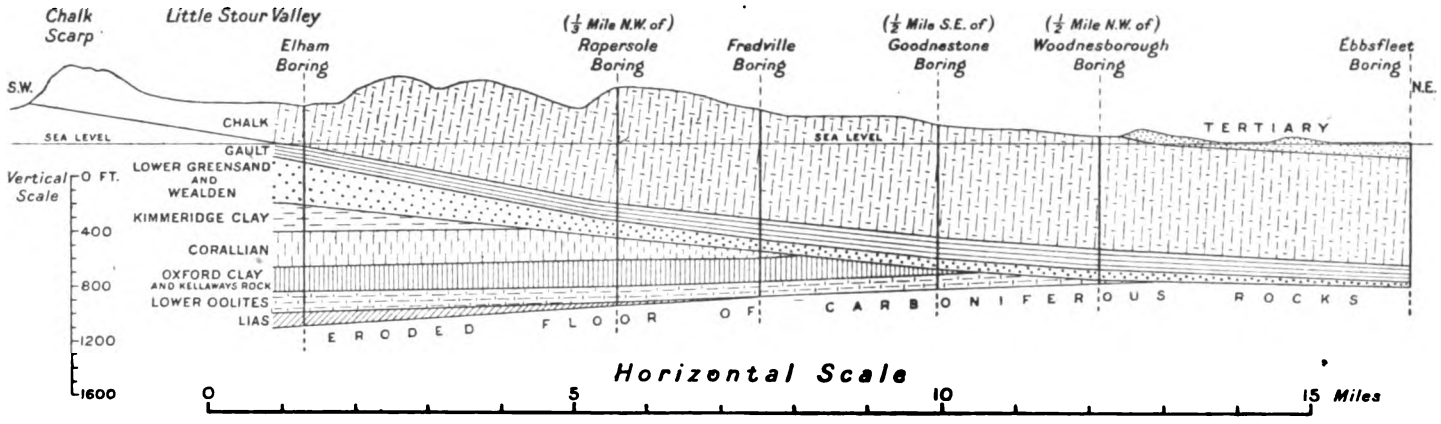
Fig. 3.—Section across East Kent, along the line shown in Fig. 2.

Vertical Scale 10 times the Horizontal Scale.



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The Lower Greensand appears to be less regular in thickness, though increasing as a whole southward and south-westward like the Wealden beds. At Ebbsfleet it is 36 ft. thick, but is apparently rather less than this at two or three places farther south, and not much thicker in certain borings to the westward. Nevertheless, on reaching Dover it has expanded to 130 ft., and at Brabourne it is 237 feet thick. The Atherfield Clay forms the lowest portion of the series over most of the area, but was not found in some of the north-easterly and north-westerly sections. In most places the greater part of the Lower Greensand consists of beds of the 'Sandgate' type—muddy and loamy glauconitic sands and clays—with a thin bed of coarser and cleaner glauconitic sand of 'Folkestone' type at the top, the uppermost portion of which is usually indurated into a concretionary band of hard calcareous glauconite-grit. No beds of the 'Hythe' type were found in any of the borings. The Atherfield Clay, where present, appears to have suffered some erosion before the 'Sandgate beds' were deposited, probably by current-action on a sea-bottom.

From the section forming Fig. 3 it will be seen that the Jurassic and Lower Cretaceous rocks together form a great wedge with a northward apex, intervening between the Palæozoic floor and the basal bed of the Upper Cretaceous. The N.N.E. dip in the Cretaceous rocks is thus changed to a S.S.W. dip in the Jurassic rocks, and the northern part of the great superficial anticline of the Weald is found to be superimposed upon a syncline of the deeper rocks. This structure was demonstrable from the evidence of the four early borings dealt with in the memoir already referred to, but it is brought out much more clearly by the later borings. The Battle boring described in preceding pages (pp. 40-44) shows that the Jurassic rocks rise southwards, and become thinner under the southern side of the Wealden dome.

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

1917.

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SUMMARY OF PROGRESS

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FOR 1917.

I.—INTRODUCTION.

By A. Strahan, Sc.D., LL.D., F.R.S., Director.

During the year 1917 the investigations of the resources of economic minerals which had been put in hand in previous years were continued. The main part of the field-work upon refractory materials having been completed, and the results so far written up as to enable a volume dealing with the occurrences and geology of the materials to be sent to the printer, an investigation of the iron ores of Great Britain was commenced. At the same time no opportunity was lost of examining the more important boreholes which were being made in search of coal, iron, oil, water, etc., both in England and Wales and in Scotland. In Scotland also some revision of the Carboniferous rocks in Lanarkshire was carried out for the purposes of the Memoir on Area VI. of the Central Coalfield, and additional information on some fireclays and sandstones in Ayrshire and Sutherlandshire was obtained.

Felspar, which was considered chiefly as a possible source of potash in 'Special Reports of the Mineral Resources of Great Britain,' Vol. V., has been the subject of much enquiry. Before the War most of the felspar used in Britain in the glass, enamel and pottery trades was imported from Sweden and Norway, and the difficulty of maintaining the supply under existing conditions has directed attention to our home resources, and necessitated further examination of the Scottish occurrences. This work was entrusted to Dr. R. Campbell, of the University of Edinburgh, who was appointed a temporary member of the staff for the purpose. Dr. Campbell's report will be found on pp. 30-34; it shows that there are several localities, not difficult of access, where felspar can be obtained in commercial quantities.

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Requests for reports on the geology of the alternative routes which are being considered for the Mid-Scotland Ship Canal have led to the collecting of additional information on the distribution of the superficial deposits and on the features of certain buried preglacial valleys. The results are summarised on pp. 34-36.

The boring near Market Weighton (p. 42), for the publication of which permission has now been kindly granted by Messrs. J. and T. Mitchell, and more recent borings at Bilsthorpe, Edingley, Farnsfield and Wellow, which have been under the observation of Dr. Gibson, have afforded much information on the structure of a part of the concealed Yorkshire and Nottinghamshire coalfield. The possibilities of the area, which extends from the Trent near Nottingham northwards to the Humber, were considered by the Royal Commission on Coal Supplies in 1901-05, but at that time the information was scanty. The chief results of later exploration, so far as regards their practical bearing, can be briefly summarised as follows.

The cover of Triassic and Permian rocks, by which the coalfield is concealed, increases in thickness eastwards at a constant rate. The increase and its uniformity are due to the eastward slope and uniform gradient of the floor upon which those formations rest. These characters were illustrated by the map forming Plate I. of the Concealed Coalfield of Yorkshire and Nottinghamshire, published in 1913. The correctness of the contour lines in the Palæozoic floor there shown is confirmed by recent explorations, and the lines can now be extended northwards, and eastwards to the 3,000 ft. level. The Trias and the Permian reach the greatest thickness yet proved, more than 3,000 ft., at Market Weighton, in a region where the Jurassic and Cretaceous formations are not only individually thin, but where the Upper Cretaceous overlaps several of the underlying subdivisions and comes to rest on the Lower Lias.

The basal bed of the Permian is composed of hard breccia south of Retford, but consists of shales or of unconsolidated sandrock north of Retford.

The eastern margin of the concealed Coal Measures lies near the Trent, and it is therefore doubtful whether the Top Hard (Barnsley) Coal, lying some distance above their base, extends so far as that river.

The Top Hard Coal, wherever it has been proved, shows changes in passing from one part to another of the concealed area, corresponding to those which it shows in the visible coalfield.

Some of the seams which lie above the Top Hard are of workable thickness in the concealed area. They may even, as in the case of the High Hazles or Kents Thick Coal, attain a greater thickness than in the visible coalfield.

The Upper Coal Measures, consisting chiefly of red marls and sandstones, survive only in the deepest parts of the syncline, and are confined to an area south of Retford. They are conformable to the Middle Coal Measures, but were extensively denuded before the deposition of the Magnesian Limestone Series. The

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depths to the Top Hard (Barnsley) Coal vary greatly in neighbouring explorations, and the existence of some powerful dislocations in the Coal Measures must be inferred. On this subject reference should be made to the account of the Kelham borehole, which forms Appendix III.

The increased demand for Tungsten Ores brought about by the war has led to important developments in Cornwall and Devon. Mr. Dewey reports that new lodes have been discovered and are being worked at Castle an Dinas near Roche, where a north and south-bearing lode in killas is said to assay 2 per cent. wolfram; at Hemerdon Tor near Plymouth, where a plexus of greisens in mineralised granite covers nearly 18 acres with a reputed reserve of a million tons of 2 per cent. ore; and at Kit Hill, Callington, where trenches have proved many lodes in the granite.

Parkanchy, an old mine, has been re-opened under Government subsidy; the south lode has so far proved satisfactory with assay values of 4 per cent. tin and wolfram. Some alluvial propositions on Bodmin Moor are being exploited on a large scale. The principal wolfram mines, South Crofty, East Pool and Tincroft, have increased their output of ore.

A magnetic survey of Great Britain, recently carried out by Mr. G. W. Walker, F.R.S., has disclosed the existence in certain parts of the country of disturbing forces, of which no explanation has as yet been found. It was suggested that the disturbances might be due to concealed masses of iron ores, and the matter was therefore laid for consideration before an Iron-ore Committee appointed by the Conjoint Board of Scientific Societies. The Committee formed an opinion that more detailed magnetic observations ought to be made in certain districts in which the disturbing forces had been observed, and that they should be accompanied by a petrological examination of the rocks, with a view to ascertaining what their magnetic effects might be. As a result two districts were re-examined by Mr. Walker, one near Melton Mowbray and the other near Irthlingboro'. In both cases questions of possible economic importance were involved, inasmuch as iron ores are being worked in the neighbourhood.

The carrying out of the petrological survey, which necessarily included both outcropping and deep-seated rocks, was undertaken by the Geological Survey, and the work was entrusted to Dr. A. H. Cox, who was appointed a temporary member of the staff in September, 1917, for the purpose. In the course of the autumn Dr. Cox collected representative specimens of the rocks accessible at the surface and was furnished by the Survey with specimens of those which were obtainable only from boreholes. The specimens have been examined as regards their petrological and chemical characters by Dr. Cox, and as regards their magnetic properties by Professor E. Wilson. A joint report by Mr. Walker, Prof. Wilson and Dr. Cox is in preparation.

On the subject of iron ores, as on other economic applications

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of geology, much information is scattered through various Geological Survey Memoirs.

The 'Iron Ores of Great Britain,' which was commenced in 1856, and of which four parts had been published by 1862, dealt with the Northern and North Midland Counties of England, South Staffordshire, South Wales and the Shropshire and North Staffordshire Coalfields. For precision and accuracy of analysis these records would be difficult to surpass, but they cover a part of the kingdom only, and leave untouched some of the areas from which a large proportion of our ore is now derived. The Mesozoic ores, which are abundant but of low grade, and the products of lodes, etc., are described in various memoirs for many but not all parts of the country. The active developments of recent years, however, have rendered it necessary to bring the information up to date for all regions. The field-work, therefore, has included an examination of existing workings, with a view to ascertaining the mode of occurrence, the characters and probable extensions of the deposits being worked.

The classification of the ores adopted is based upon the mode of occurrence. They fall into three classes, namely, those products, mostly Hematites, which occur in lodes, as replacements, etc.; the Mesozoic Ores which take their places in the sedimentary series as bedded calcareous or sandy strata with a varying proportion of the carbonates or oxides of iron; the Clay-ironstones which with Blackbands abound in the Coal Measures, and which have been worked also in the Wealden and Yoredale Beds of England. The Scottish ores, which range through the Coal Measures, Millstone Grit, the Upper Limestone group, the Limestone Coal group, and the Lower Limestone group belong to this class, with the exception of the Mesozoic ore of Raasay.

The field-work was completed before the expiration of the year. The Mesozoic ironstone works were examined by Mr. Lamplugh, Mr. Wedd and Mr. Pringle, under the superintendence of the first-named, who himself furnishes an account of the Cleveland district. Lincolnshire, Rutland, Northamptonshire, Hunts and Leicester were reported on by Mr. Wedd; Oxfordshire, Warwickshire, Wiltshire and Dorset, by Mr. Pringle. The reports on the Coal Measures and kindred ores (apart from those of South Wales), were prepared by Dr. Gibson, who was assisted in Staffordshire and Shropshire by Mr. Dewey, and in Northumberland by Dr. Sherlock. The various occurrences of hematites, etc., in lodes, etc. (apart from those of the Forest of Dean and South Wales) were investigated by Mr. Smith, Dr. Sherlock, and Mr. Dewey, under the superintendence of Mr. Cantrill. The hematite occurrences of Cumberland and Lancashire were examined by Mr. Smith, the lodes and occurrences of hematites and pisolitic ores in North Wales by Mr. Cantrill and Dr. Sherlock, the lodes of Cornwall and Devon by Mr. Dewey, and those of the Brendon Hills and Exmoor by Mr. Cantrill and Dr. Sherlock. At the same time an exhaustive examination of the hematite deposits of the Forest of Dean and of South Wales (with Monmouthshire) was in progress by Prof. T. F. Sibly, who had generously placed his services, and the knowledge of the Forest

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that he had already gained, at the service of the Geological Survey. This investigation is yielding results of great scientific and economic importance.

In Scotland the field-work on iron ores was carried out in Raasay and in Fife by Dr. G. W. Lee; in Midlothian, Haddington and the Coal Measures of Fifeshire by Mr. T. Robertson; in Ayrshire by Mr. G. V. Wilson; and in the Central Coalfield by Mr. M. Macgregor.

The difficult problem of estimating reserves in undeveloped ground involved a close inquiry into the geological conditions prevailing in and around the proved areas. It assumed its simplest form in the case of the bedded ores, such as those of the Mesozoic formations and the Coal Measures. The Mesozoic ores occur mainly in the Lower and Middle Lias, the Northampton Sands, the Corallian and the Lower Greensand. In each case the outcrop of the ore-bed can be traced, and the part of it which is workable determined. Its horizontal extent underground as a payable ore remained an uncertain factor, and this has been partly determined by recent mining exploration. As regards the Coal Measure ores also, which were once most important sources in South Wales, Staffordshire, Shropshire and elsewhere, the reserves are calculable, but the demand for the ores has so dwindled, chiefly in consequence of the competition from cheaper sources, that the labour involved in making detailed estimates of the undoubtedly great reserves is not justifiable in all cases. The Blackbands of North Staffordshire are exceptional.

As regards the reserves of hematite and other iron ores in lodes and pockets, the problem is far different. The productiveness of a lode, the extent of a pocket or the location of new pockets, are matters which it is impossible to predict with precision. A study of the conditions, however, under which the ores have been formed renders it possible to define, more or less closely, the areas in which further deposits are likely to occur. Thus in the case of the hematite deposits of Cumberland and Lancashire, the association of the ores with lines of fault, with certain beds of the Carboniferous Limestone cut by the faults, and lastly with the former distribution of the Permian and Triassic rocks, has been established over what may be called the visible ore-field. Other tracts where the Permian or Triassic rocks still exist, and where the Limestone may be inferred, on geological reasoning, to underlie them under suitable conditions, are regarded as concealed ore-fields. Estimates of their contents are made on the assumption that they contain ore in the same proportion as the ore-fields already worked.

In the Forest of Dean the chief ore-bodies occur in the upper part of the Carboniferous Limestone Series, which crops out round the greater part of the coalfield. By operations extending through several centuries their existence has been proved over a part of the outcrop, and for this part Prof. Sibly has found a calculation of reserves possible. On the other hand how far the ore-bodies extend, or whether they are equally abundant, beneath the coalfield, has not been ascertained, and for

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this concealed ore-field no estimate is attempted. It remains as a possible but unknown reserve.

In Glamorganshire the hematites occur in the upper part of the Carboniferous Limestone, and their formation here has clearly been dependent upon the former distribution of Triassic rocks. As in Cumberland and Lancashire there exists in Glamorganshire a visible ore-field, which has been partly exploited; and a field concealed by red rocks, as yet little exploited, but regarded by Prof. Sibly as being of considerable promise. Estimates of the reserves of the concealed field are founded on a consideration of the area over which suitable geological conditions extend, and on the assumption that the yield will be proportionate to that of the ground already worked.

The lodes offer a still more difficult case. Few are being worked, some having been worked out, others exhausted to water-level, but that several contain reserves of ore is certain. The estimate in such cases is founded on the assumption that, in the aggregate, the lodes contain a reserve of ore equal to the aggregate output of the last 10 years, or in some cases the last 20 years, of the mining operations. This basis, arbitrary as it is, leads to an estimate bearing some relation to the proved productiveness of past years.

The estimates of iron ores that have been made by the various methods described above are set out in the following table. They are, on the whole, framed in a cautious spirit, with an intention to avoid overstatement of reserves. Even so the reserves of all classes of iron-ore reach an enormous figure. It must be remembered, however, that a limiting factor on their development exists in the low value of ironstone. Low-grade ores, such as those of the Mesozoic rocks, command a price but little better than that of ordinary stone. In our present enquiry we have been concerned only with the quantities which exist; the quantity that can be profitably worked will depend upon future contingencies.

GREAT BRITAIN.

Hematites, etc.

	Reserves more or less developed. Tons.	Probable additional Reserves. Tons.
Cumberland and Lancashire...	40,000,000	70,000,000
Durham (Weardale)	—	250,000
Gloucestershire (Forest of Dean)	2,500,000	—
South Wales (Llanharry District)	—	4,000,000
Cornwall and Devon	—	500,000
Somerset (Brendon and Exmoor)	—	250,000
North Wales (Carnarvon and Merioneth) ...		
Isle of Man		
	42,500,000	75,000,000

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	Reserves more or less developed. Tons.	Probable additional Reserves. Tons.
Yorkshire (Cleveland), Main Seam	190,000,000	150,000,000
Do. Pecten Seam ...	—	40,000,000
Do. Two-foot Seam ...	—	50,000,000
Do. Avicula Seam ...	—	10,000,000
Do. Top Seam	—	1,000,000
Lincolnshire, Frodingham Bed	162,000,000	336,000,000[2]
Do. Marlstone	36,000,000	—
Do. Northampton Bed	51,000,000[1]	360,000,000[2]
Do. Claxby Bed	—	4,500,000
Leicestershire, Marlstone	62,000,000	—
Rutland, Northampton Bed	86,000,000	—
Northants. and Hunts., Northampton Bed	1,115,000,000[1]	616,000,000[2]
Oxfordshire and Warwickshire, Marlstone	37,000,000	386,000,000
Wiltshire (Seend), Lower Greensand ...	—	5,500,000
Do. (Westbury), Corallian	26,000,000	22,500,000
Dorset (Abbotsbury), Corallian	—	11,500,000
Kent (Dover), Corallian	—	100,000,000
Inverness-shire (Raasay), Upper Lias ...	10,052,160	11,886,000
	1,775,052,160	2,104,886,000

Clay-Ironstones and Blackbands from Carboniferous and Wealden Beds.

Northumberland (Redesdale)	—	1,500,000
Yorkshire	110,760,000	104,320,000
Derbyshire and part of Notts	566,560,000	13,440,000
Warwickshire	4,608,000	—
Staffordshire, North	364,417,000[3]	939,883,000
Do. South (with Worcestershire)	11,520,000	62,680,000
Shropshire	—	30,000,000
Flintshire and Denbighshire...	—	20,000,000
South Wales and Monmouthshire	upwards of	5,000,000,000
Sussex and Kent (Wealden Beds)[4] ..	—	—
Fife	407,000	962,000[5]
Midlothian	185,000	2,117,400[5]
Ayrshire...	7,150,000	55,000,000[5]
Central Coalfield of Scotland	30,000	18,573,200[5]
	1,065,637,000	6,248,475,600

[1] This represents an area over which workable stone is known to occur near the surface, but of which a small part only in Lincolnshire, and a somewhat larger part in Northamptonshire, has at present been taken up.

[2] This represents an area under which workable stone is known or may be reasonably inferred to occur, but requires mining.

[3] Blackband Ironstones.

[4] An important source of ore till 1828. The ore is far from exhausted, but is nowhere worked.

[5] In addition to the estimates given under the head "Probable additional Reserves," the following are regarded as Possible Additional Reserves :—

	Tons.
Fife	6,874,400
Midlothian	4,646,000
Ayrshire	69,140,000
Central Coalfield...	318,414,000
	399,074,400

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	Reserves more or less developed. Tons.	Probable additional Reserves. Tons.
Hematites, etc.	42,500,000	75,000,000
Mesozoic Ores	1,775,052,160	2,104,886,000
Clay-ironstones and Blackbands	1,065,637,000	6,248,475,600
	2,883,189,160	8,428,361,600

Grand total of all ores for Great Britain, 11,311,550,760 tons.

II.—FIELD WORK.

In the following summary the results of the field-work on iron-ores are referred to only so far as to show the methods by which the estimates given in the Table on pp. 6-7 have been obtained.

(1). Hematites, Etc.

CUMBERLAND AND LANCASHIRE.

From notes by B. Smith.

The output for this district was in 1915 1,656,484 tons, of which 333,086 tons were raised in the Furness district of Lancashire.

The reserve regarded as proved may be estimated at:—

Cumberland ...	Lamplugh-Beckermet district Millom district	30,000,000 to 40,000,000
Lancashire ...	Furness district...	3,500,000 to 4,000,000

or approximately 40,000,000 tons in all.

As regards further reserves in unproved ground, estimates are difficult partly in consequence of the sporadic occurrence of the ore-bodies, and partly because the Carboniferous Limestone, in which most of them occur, is covered by glacial deposits, or by red sandstone and breccia that may attain a thickness of 1,000 ft. or more. To prove such areas a systematic exploration by boring is essential.

One of the largest reserves for future exploration may occur in the unproved tract of New Red Sandstone which extends southwards from Egremont. Between Ullcoats and Winscales the existence of 20,000,000 to 30,000,000 tons has been proved by recent explorations, at depths ranging from 700 to 1,000 ft. The eastern limit of the productive area is likely to continue through Hale and Ponsonby Hall, and the western limit, along the valley of the Eden to St. John Beckermet and thence by Yottenfews. Farther south the Carboniferous Limestone may not be present or, if present, is likely to lie at a great depth. A borehole at Seascale, 2½ miles south of Yottenfews, failed to bottom the New Red Sandstone at 3,200 ft.[1] The area defined above contains approximately 5 square miles, and provided that the limestone underlies it and is productive in the same proportion as the ore-field already worked, it may contain a reserve of 40,000,000 to

[1] 'Summary of Progress for 1909,' *Mem. Geol. Survey*, 1910, p. 53, and J. W. Gregory, *Geol. Mag.* for 1915, p. 146.

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50,000,000 tons, in addition to the reserve mentioned above as having been proved.

Another possible reserve extends for about 1½ miles N.W. of the Helder Pit, Egremont. Neither the existence nor the accessibility of the reserve have yet been ascertained, and no allowance is made for it in the estimate.

In the Millom district ore may be assumed to occur as freely in the Carboniferous Limestone below the Duddon estuary as in Furness generally. On this assumption a reserve of 24,000,000 tons is estimated for the unexplored area lying between Hodbarrow and the mines situated east of the Duddon.

Minor reserves of ore, difficult of access, occur in the Eskdale granite, Skiddaw slate, and in the rocks of the Sca Fell group.

In the Furness district some reserves probably exist in the deeper parts of veins which were abandoned through water trouble, but the largest deposits are likely to be found near the Duddon estuary and in the Dalton-Ulverston region. Prospects are less good south-eastwards towards the western shore of Morecambe Bay. Apart from any ores to be found in the deeper parts of the veins, the estimates for Furness amount to about 12,000,000 tons and are included in the 24,000,000 tons estimated for the Duddon estuary.

The composition of the Cumberland hematite is shown by the following analyses:—

	Blast Furnace Ore average from 15 mines (not including Hodbarrow).	Hodbarrow Ore average.
	Per cent.	Per cent.
Metallic iron	51·57	57 to 58
Insoluble residue	11·90	3·5
Phosphorus	·0077	·006
Calcium carbonate	3·02	
Moisture	4·26	6·0

The Furness ore is similar in composition. The ore of the Nigel Pit, Roanhead Mine, is almost as rich in metallic iron as that of Hodbarrow, but the insoluble residue is larger, silica ranging up to 14 per cent.

DURHAM (WEARDALE).

From notes by R. L. Sherlock.

The ores occur in the Yoredale Beds in connection with fissures which develop a breadth of several feet in some of the limestones, but may be represented by a mere film in the intervening shales. They are described as brown hematites, and according to an analysis furnished by the Weardale Steel, Coal and Coke Co., Ltd., yield, after drying, 40·8 per cent. metallic iron with about 9 per cent. of silica. The percentage of metallic iron has increased in the ore worked in late years. In depth the ores are spathic.

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GLOUCESTERSHIRE (FOREST OF DEAN).

From notes by Prof. T. F. Sibly.

The ores are exclusively hematites.[1] The chief deposits lie in the upper beds of the Carboniferous Limestone Series, which crop all round the coal-basin except over a distance of about 3 miles on the northern margin and an equal distance on the south-eastern margin. Workings extending over many centuries have proved considerable deposits all along the eastern crop, and as far north as Staunton on the western crop. Only a few tracts, on the western margin between Lydney and Staunton, and on the north-eastern margin at Wigpool Common, are in process of development at the present time.

Two and a half million tons is a conservative estimate of the workable reserves of ore in the proved areas.

The unproved areas lie in the deep, and estimates of reserves within them would involve assumptions as to how far the deposits persist in depth

The ores vary greatly in iron content, and appear to vary considerably in silica content, but are always low in phosphorus and sulphur. The following analysis, quoted by permission from a report by the Deputy Gaveller of the Forest of Dean, may be regarded as giving good average values for iron, sulphur and phosphorus, but is unusually high in silica and low in lime and magnesia:—

Average sample of ore as received from Westbury Brook (Edge Hill) Mine in 1884.

	Per cent.
Peroxide of iron	50·0
Alumina	3·71
Manganese oxide	·04
Calcium carbonate	3·79
Magnesium carbonate	·88
Silica	19·25
Sulphuric acid	·03
Phosphoric acid	·06
Combined water...	8·20
Moisture	13·50
	99·46
Iron	35·0
Sulphur	·01
Phosphorus	·03

SOUTH WALES (LLANHARRY DISTRICT).

From notes by Prof. T. F. Sibly.

Considerable deposits of hematite, similar to that of the Forest of Dean, have been proved, or may reasonably be believed to exist, in a tract on the 'South Crop' of the Carboniferous Limestone which extends east and west between the Rivers Taff and Ewenny, north-west of Cardiff.

In the eastern part of this tract, lying between the Taff at Taff's Well on the east, and the Ely at Pont-y-Clun on the

[1] That is, in the commercial sense. The ores consist chiefly of hydrated ferric oxide; true hematite in the massive form rare.

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west, two or three million tons of ore were raised during the latter half of the 19th century. The reserves of ore in the unproved portions of this area are probably small.

In the western part of the tract, a strip of country about 4 miles long and $\frac{1}{5}$ to $\frac{1}{4}$ mile wide between the Ely on the east and the Ewenny on the west, a small area is in process of development at the Llanharry Mine. The total reserves of ore (*a*) in process of development at Llanharry Mine, and (*b*) existing in ground to the west of that mine not yet proved, should not be less than four or five million tons.

The following is a *typical analysis* of the ore from the Llanharry Mine, communicated by the Cardiff Hematite Iron Ore Company:—

Analysis of Llanharry Hematite Iron Ore.

By R. W. and A. J. Atkinson, July 15th, 1912.

Sampled jointly by Messrs. Atkinson and G. R. Thompson.
Eight samples in June, 1912, compounded, giving the following results:—

	In sample dried at 212° F.		
In HCl. solution.	Per cent.		Per cent.
Peroxide of iron	79·41	Metallic iron	55·59
Protoxide of manganese	0·07		
Alumina	0·221		
Lime	3·20		
Magnesia	0·19		
Sulphur	0·014		
Phosphoric acid	0·025	Phosphorus	0·011
Combined water	7·80		
Carbonic acid	2·50		
Insoluble in HCl.			
Silica	5·87		
Alumina	0·44		
Lime	0·26		
Titanium	absent		
	100·00		

Moisture, 7·30 per cent. Iron (raw), 51·53 per cent. Mechanical condition, 25 per cent. lump, 25 per cent. rubble, 50 per cent. small (not fine).

CORNWALL AND DEVON.

From notes by H. Dewey.

Hematites, carbonates, magnetite and pyrites occur in the outer fringes of the tin and copper mining regions. The principal iron-mines are situated near the St. Austell granite in Cornwall and on the eastern edge of the Dartmoor granite in Devon. Several minor lodes have been worked near Bodmin and St. Austell.

In Cornwall the Perran Iron Lode can be traced for upwards of 8 miles, with a width ranging up to 50 ft. It contains in places much breccia, mostly of quartz. The following mines upon the lode are taken in order from the coast eastwards:—Gravel Hill (Penhale Iron Mine), Halwyn, Mount and Trebisken, Treamble, Great Retallack, Duchy Peru, Deer Park and Penhallow Moor.

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Considerable lengths of untouched lode intervene between these mines, but it must not be assumed that they will be continuously and equally productive. At the Duchy Peru Mine, where breccia was greatly developed, the lode died out both in depth and laterally.

Masses of iron ore, several fathoms thick, were found at the intersection of the lode with north-and-south lead- and zinc-lodes. As a rule about half the contents of the lode were iron ore. The ore occurs as carbonate, but changes near the surface into brown hematite or limonite.

In the brown hematite of the Treamble Mine, according to various analyses, the metallic iron varied from 55·7 to 60 per cent., phosphoric acid from a trace to ·86, manganese oxide up to ·8, silica from 1·2 up to 5 per cent. In the carbonate ore the loss by calcination was 32·8, the metallic iron 54·30, and metallic manganese 8·10 per cent. Phosphoric acid occurred in traces only, and it is believed that its presence in the brown hematite is due to its having been introduced by surface-water.

North of Lostwithiel a series of large open workings extends for half a mile. The ore consisted of brown and red hematite (reputed to contain 44 per cent. metallic iron), and the total yield up to 1883 was 121,796 tons. It is doubtful whether much ore remains above the 12-fathom level, that is—the first level below adit. In places the mine is 400 ft. deep.

Near Bodmin several minor lodes difficult of access have yielded hematite. The reserves appear to be small.

In Devon magnetite, specular iron ore and brown hematite occur.

At Hay Tor Mine there are, according to an old plan, three beds of magnetite, 8 ft., 13 ft., and 5 ft. thick, but the three beds now being worked near the surface measure 1½ ft., 2 ft., and 3½ ft. respectively. Hematite has been worked opencast along the lode for nearly a mile, and the weathered ore shows included lumps of magnetite. The old adit is being reopened and new shafts are being sunk. The present output of 60 to 70 tons a month is likely to be increased.

The percentage of iron in the magnetite ranges between 40 and 70.[1]

In the Sharkham Mine, near Brixham, hematite occurs in pockets in Devonian Limestone.

Many pockets have been worked out, but the area is not exhausted. The ore is graded into 'firsts,' containing 60 per cent. of iron, and 'seconds,' with 30 per cent. Silica ranges up to 20 per cent. Sulphur, phosphorus and manganese are low.

Specular Iron Ore, known as 'Shining Ore' or 'Devonshire Sand,' occurs in narrow veins in the granite of eastern Dartmoor. It is being still dug at the Kelly Mine, Lustleigh, and the Great Rock Mine, Hennock. The ore is used for making paint and other purposes.

[1] 'The Geology of Dartmoor,' *Mem. Geol. Surv.*, 1912, pp. 79, 80.

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From notes by T. C. Cantrill and R. L. Sherlock.

In the Brendon Hills the ore occurs in pockets on veins in Devonian rocks. The pockets may be close together or as much as a mile apart, and may reach a length of 600 yds. along the vein with a width up to 30 ft., and a depth proved to reach 1,000 ft. The veins agree in direction with the strike of the rocks and dip southwards at 45° to 65°. 'Brown hematite,' 'black ore' (hematite with psilomelane), 'potty ore' (cellular hematite), 'red ore' (spathose ore with hematite) and 'white ore' (poor spathose ore) were raised. The ore yielded spiegeleisen of good quality containing about 20 per cent. of manganese. (J. A. Phillips, 'A Treatise on Ore Deposits,' Ed. 2, 1890). An estimate was made in 1868 by Mr. Morgan Morgans, who had been connected with the mines for nine years, that there existed a reserve of 12,000,000 tons within 300 fathoms of the surface.[1] Since then only 444,000 tons have been raised, and the mines are now abandoned. The estimate, therefore, appears to have been too optimistic, and the reserves must be regarded as doubtful.

On Exmoor the mode of occurrence appears to have been the same as at Brendon Hills. Veins have been worked at various places, but their continuity remains to be proved. They may be continuous with those of Brendon Hills.

Analyses of the Brendon and Exmoor ores are given in the *Quart. Journ. Geol. Soc.*, vol. xv, 1859, p. 105.

NORTH WALES (CARNARVONSHIRE, MERIONETH AND ANGLESEY).

From Notes by T. C. Cantrill and R. L. Sherlock.

In Carnarvonshire, Merioneth and Anglesey, pisolitic iron ores, interbedded in Ordovician shales, have been worked at widely separated localities. Though not continuous, ore-beds are certainly more extensive than has yet been proved, but to trace their outcrop and to determine the variations in their characters would require a detailed survey of the stratigraphy of the whole district. The thickness of one of the beds worked has been found to range up to 23 ft., and in one case the ore is associated with a bed of manganese ore 3 ft. thick. These pisolitic ores of North Wales have so far not found favour with the ironmasters. An analysis of the ore from Bettws Garmon, made when the best quality was being got, shows 40 per cent. of metallic iron and 1·62 of phosphorus in the dried ore. The ore now being worked shows 30 per cent. of iron.

Hematite has been worked in the Carboniferous Limestone, but on a small scale and apparently to exhaustion. At Nantuchaf it was raised in connection with manganese. All the mines are inactive, but proposals to test the ground between Cwm and Dyserth Station by an adit are under consideration. The reserves, if any exist, from these hematites are not included in the estimates for North Wales.

[1] *Trans. S. Wales Inst. Eng.*, vol. vi, 1870.

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From notes by G. W. Lamplugh, F.R.S.

Veins carrying hematite and some spathose ore occur in the Manx Slates (Cambrian?) in the north-eastern part of the Isle of Man and have been mined, particularly between the years 1854 and 1881, when they yielded in the aggregate 12,896 tons of hematite. The ore occurred in detached bunches, and the mining was never profitable. Such reserves as may exist cannot be estimated at more than a few thousand tons.

In the northern part of the island an area of Carboniferous Limestone, of unknown extent, is buried deeply under Glacial deposits. The conditions of this limestone resemble those of the hematite-bearing limestones of Cumberland. The possibility of hematite occurring in this tract has been frequently discussed, but has been hitherto regarded as too speculative to be tested practically by borings.

(2) Mesozoic Ores.

YORKSHIRE (THE CLEVELAND DISTRICT).

From notes by G. W. Lamplugh, F.R.S.

The seams of ironstone recognised in the Cleveland District occur in the Lower Oolite and the Middle Lias.

Table of seams.

	Thickness. Ft.
Top or Oolite Seam	impersistent; 4 ft. to 7 ft. in present workings.
Strata (Upper Lias)	240
Main Seam	6 to 11
Strata	2 to 5
Pecten Seam	1⅛ to 6
Strata	3 to 6
Two-foot Seam	1½ to 2½
Strata	20 to 30
Avicula Seam	0 to 3

Practically the whole of the working is done by deep mining, partly by day-levels and partly by shafts ranging up to about 700 ft. in depth. The workings are at present nearly all confined to the Main Seam.

The Top Seam is extremely variable in composition and thickness. At present only two patches are being worked, and the reserves in these probably do not exceed one or two millions of tons of ore averaging 30 per cent. of iron. Two rich pockets of magnetic ironstone were found in this bed in Rosedale about 70 years ago, but borings have as yet failed to disclose further masses of this kind.

The Main Seam occurs at the surface in the northern part of the district but dips southwards underground. In the north-western part, now practically exhausted, the seam was 9 to 11 ft. thick, consisting of good ore throughout, and in the raw state containing 30 to 35 per cent. of iron. Southwards it deteriorates and is split by a parting of shale. Where the shale first sets in there is usually about 4 ft. of good stone above and about 3 ft.

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below it. Most of the present mines are working across this belt, which contains large reserves of ore averaging in the raw 30 per cent. of iron. Still farther southwards the shale has thickened to 2 ft. and the workable ore has diminished to 5 ft. or less with an average iron-content of 27 per cent. The royalties at present being worked cover the area to which all the above remarks refer, and contain a reserve estimated at 190 millions of tons.

Farther south the seam continues to deteriorate and within 2 or 3 miles becomes worthless, being broken up into strings and bands of nodules in shale. The intervening ground contains a quantity of ore which may be worth extracting under favourable economic conditions, and may be estimated at 150 millions of tons.

The Pecten and Two-foot Seams have been worked in small quantities in conjunction with the Main Seam in the northern area. The Pecten and Avicula Seams have also been worked independently at Grosmont and other places in the Esk valley where the Main Seam is not developed. The Pecten Seam yields ore of low quality and is in places too much mixed with shale to be of value. The Two-foot Seam is fairly constant and of medium quality in the northern and western part of the district, but splits up and deteriorates in the southern part.

The Avicula Seam is fairly persistent, but shaly and lean. Locally in the Esk Valley it improves, and has yielded at Grosmont 7,500 to 8,000 tons per acre, averaging about 25 per cent. iron in the raw stone.

LINCOLNSHIRE, LEICESTERSHIRE, RUTLAND AND NORTHAMPTONSHIRE (WITH HUNTS).

From notes by C. B. Wedd.

Three ore-beds are in use in various parts of these counties. The Northampton Bed forming the basal part of the Interior Oolite is worked in Lincolnshire, Rutland and Northamptonshire; the Marlstone Bed of the Middle Lias is worked in Leicestershire and Lincolnshire; the Frodingham Bed of the Lower Lias is worked in Lincolnshire. All are quarried in open workings, except a small but increasing proportion of the Northampton Bed which is mined at shallow depths. Besides these the Claxby Bed of Lower Cretaceous age has been worked in Lincolnshire, but has been rejected of late years. It contains about 30 per cent. of iron and is of siliceous and slightly calcareous nature. The estimate of reserves of the Claxby Bed is based on the supposition that 3 ft. of ore would be available over an area of one square mile. The actual thickness and extent are considerably greater.

The estimates of ironstone reserves set forth in the table are based on present-day requirements, without reference to the possibility of utilising lower grade ore at some future date.

The Frodingham Bed is a calcareous ore with about 1 per cent. manganese and ·3 of phosphorus. The dried stone contains 20 to 25 per cent. of iron. The cover removed in working it ranges

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from nil to upwards of 60 ft., and the removal of 100 ft. is contemplated before resorting to mining.

The Marlstone Bed is partly siliceous, partly calcareous with about ·3 to ·4 per cent. of manganese, and ·3 of phosphorus. The dried stone contains 32 per cent. of iron, and the cover removed ranges up to 15 ft. in thickness. Under a greater thickness of cover the Marlstone of the Midlands becomes too calcareous to be worked as an ironstone.

The Northampton Bed is siliceous, with ·1 to ·3 per cent. of manganese and ·3 to ·7 of phosphorus. The dried stone averages about 38 per cent. of iron, and the cover removed ranges up to 40 ft. in thickness.

The large reserves estimated for the Northampton Bed lie mainly in Northamptonshire. The area occupied by this ironstone may be divided into:—

(*a*) A central district lying between Rockingham, Desborough, Wollaston, Thrapston, Brigstock and Dene. The ore may be assumed to be generally of workable quality, wherever it has survived denudation.

(*b*) A district extending south-westward of (*a*) at least as far as Towcester.

(*c*) A district extending northward to the northern boundary of the county. In (*b*) and (*c*) the ore has not been proved to keep its quality throughout, and only those parts in which it is known to do so are taken into account. A further district, also, lying eastward and south-eastward of the Nene Valley, where the ironstone finally passes under cover, is as yet untried. The reserves may be great, but are not included in the estimates.

NORTHAMPTONSHIRE (*Contd.*), OXFORDSHIRE AND WARWICKSHIRE.

From notes by J. Pringle.

In Northamptonshire the Marlstone Bed occupies an area lying between Daventry and Bugbrook and extending southwards, but little is known of its quality further than that it contains 23 per cent. of iron at Kings Sutton, but is likely to vary greatly. It is being opened up at Hellidon and Byfield.

In the districts lying to the north, south and west of Banbury (Oxfordshire and Warwickshire) the Marlstone has a wide outcrop and in its upper part is generally ferruginous, but the percentage of iron is known to vary widely in different parts of the area. Owing to cost of transport and other practical difficulties the field has not yet been fully developed, though the bed has been worked on a limited scale for many years and several new workings are being commenced. Until development is further advanced, it is not possible to say how much of the field will pay for exploitation. The estimate of reserves includes exposed tracts, and all the ground in which the cover does not exceed 10 ft. in thickness.

The ore is mainly calcareous but locally siliceous, and the iron-content, where known, varies from about 20 to 30 per cent., or to a little more than 30 per cent. in the richer parts at Hook Norton and Adderbury.

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WILTSHIRE.

From notes by J. Pringle.

At Seend the iron-ore occurs in an outlier of Lower Greensand and covers an area of 179 acres, of which about 64 acres is occupied by the village. The average thickness is taken as 20 ft. and the yield 2,500 tons per foot per acre. The silica percentage is upwards of 27, and that of iron about 37. The workings ceased in 1874.

At Westbury the ore occurs in the top beds of the Corallian. At the outcrop it weathers reddish-brown, but under cover it is bluish-green and known as ' blue ore.' The crop-workings are nearly exhausted, but borings through the cover of Gault or Kimmeridge Clay have proved the existence of the ore over an area of nearly 1,500 acres. The average thickness is 11 ft. The phosphorus-content is about ·5 per cent., and metallic iron is about 30 in the raw ore, and 42·5 in the calcined ore. The ' blue ore ' loses about 30 per cent. on calcination. The insoluble silica ranges from about 11 in the ' blue ore ' to about 16 per cent. in the ' brown ore,' according to the few analyses available.

DORSET.

From notes by J. Pringle.

The ore occurs in the uppermost beds of the Corallian, and has resulted from the local alteration of a calcareous grit. It averages about 20 ft. in thickness and covers an area of about 256 acres, 60 of which are occupied by the village of Abbotsbury. The extension of the ore under the Kimmeridge Clay has not been proved, and the possible reserves thus covered are not included in the estimate. The only analysis available gives a silica-content of 42·6, and of peroxide of iron 43·97 per cent., equivalent to about 34 to 35 per cent. of iron in the roasted ore.

KENT.

From notes by G. W. Lamplugh, F.R.S.

In boring and sinking operations for coal in Kent, ferruginous deposits have been proved in the overlying Jurassic rocks, one of which occurs in the Upper Corallian formation in about the same stratigraphical position as the iron ore of Westbury, Wilts, and is of similar character. The ore is made up of brown oolitic granules embedded in a marly matrix. The iron-bearing quality of the rock depends upon the relative abundance of the granules, which varies from place to place. The best and thickest ore was found in the Dover Colliery shafts, where the bed is about 16 ft. thick and is stated to contain over 32 per cent. of iron in the raw stone. It is known to diminish in thickness and value in the interior country until it becomes worthless, but the borings have proved a workable area around Dover estimated to be about six square miles and to contain approximately 100 million tons of available ore after allowing for permanent pillars, etc.

The percentage of metallic iron in a specimen from one of the borings has been given at 32·2, that of silica 13·77, phosphorus ·4 per cent. The loss on calcination was 19·4 per cent.

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From notes by G. W. Lee.

The Raasay ore is composed of ooliths of silicate of iron embedded in limestone, and occurs as a bed in the Upper Lias. The bed ranges up to 17 ft. in thickness, being at its maximum in the southern side of the field, and gradually thinning out northwards on the eastern side of the island.

The area regarded as proved covers 370 acres with a calculated yield of 27,168 tons per acre.

A large area concealed by Oolitic formations and granophyre, as yet wholly unproved, exists in the middle and western part of the island, north of the proved area. For this a "probable reserve" of 5,094,000 tons is estimated on a basis of 300 acres at 16,980 tons per acre, but no further "possible reserves" can be safely assumed. Under the Oolitic formations of Beinn na' Leac a "probable reserve" of 6,792,000 tons is estimated, on a basis of 250 acres at 27,168 tons per acre.

Analyses show:—Metallic iron in raw ore, 25·2 (calcined 35·7); silica, 6·5; alumina, 5·6; lime, 17·6; carbon dioxide, 28·3; phosphoric acid, 2·3; sulphur, 0·2 per cent.

(3) Clay-ironstones and Black Bands from the Carboniferous and Wealden Beds.

Ironstones of the Coal Measures.

From notes by W. Gibson.

The coalfields of Yorkshire, Derbyshire, Warwickshire, Worcestershire, Staffordshire, Shropshire and South Wales contain great reserves of ironstone. These, however, occur as nodules, cakes, and thin bands generally from 1 to 3 in. in thickness, lying separately in shales from 6 to 80 ft. thick, the aggregate thickness of ironstone seldom exceeding 1 ft. Only in North Staffordshire, where the beds of ironstone range from 1 to 6 ft. in thickness, is it, at present, found profitable to mine the ironstones apart from their closely associated coals. Here are found mines whose operations are confined to raising ironstone; in the other areas ironstone is got occasionally, but only in the proportion of about 1 ton to 160 of the associated coals.

Typical analyses of the Black Bands and Semi-Black Bands of the proved area in North Staffordshire can be selected from numerous examples. As regards Shropshire, South Staffordshire, Yorkshire, Derbyshire and South Wales, the analyses given in 'The Iron Ores of Great Britain,' *Mem. Geol. Survey*, 1856-58, were made from samples obtained when the ironstones were extensively worked. They should therefore represent the average composition more truly than would specimens from the particular districts to which the limited workings of the present day are confined.

The reserves of ore can be estimated with considerable accuracy in North Staffordshire, but in the majority of coalfields the necessary data are wanting. This applies to the yield per acre, and to the area over which any particular bed may extend. The old

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workings were situated where the yield was profitable and only such records as were made in sinking shafts exist for other sites. Again, in raising ironstones from coal-mines the stone is only obtained during some process necessitating its removal to the surface. The yield therefore may be above or below the average. Further, many of the ironstones are capricious in their occurrence. Estimates for the unproved areas are therefore only given for such beds as are known to be fairly constant over the proved areas.

In all cases, probably as much as 10 per cent. should be deducted from the estimates to give the amount of ore it would be possible to get at a profit in working the associated coals exclusive of losses due to faults, barriers and other causes.

Abundant as are the ironstones of the Coal Measures of the counties named in the Table on p. 7, they would not replace the equally rich, more easily wrought and cheaply got Mesozoic ores even under favourable conditions as regards proximity to existing furnaces. The comparatively small quantities of clay-ironstones, other than black bands, at present raised from the Coal Measures are almost exclusively used in the production of high-priced pig-iron.

YORKSHIRE.

From notes by W. Gibson.

The Low Moor Ironstone has been regarded as a source of an exceptional quality of iron, a reputation gained partly through the care exercised in cleaning it and the purity of the coal used for smelting it. It is developed in the neighbourhood of the northern part of the coalfield, between Leeds and Bradford, and occurs as 3 to 10 in. of ore in about 30 in. of shale. The percentage of iron averages about 29.

The Clay Wood and White Mine Ironstone occurs in the neighbourhood of Sheffield as 3 courses in 6 to 10 ft. of shale. Metallic iron averages about 31 per cent. The Tankersley Ironstone is developed between Barnsley and Sheffield, and consists of 12 to 15 in. of ore in 6 ft. of shale. Metallic iron ranges from 16 to 27 per cent.

	Yield per acre. Tons.	Developed area. Tons.	Additional reserve. Tons.
Low Moor Ironstone	1,000	3,840,000	38,400,000
Clay Wood and White Mine Ironstone	1,500	53,760,000	40,320,000
Tankersley Ironstone	2,000	35,840,000	25,600,000
Ironstone of restricted occurrence ...	—	17,320,000	—
		110,760,000	104,320,000
		215,080,000	

DERBYSHIRE AND PARTS OF NOTTS.

From notes by W. Gibson.

The Dale Moor Rake and Civilly Rake are developed near the southern margin of the coalfield and contain 27 to 33 per cent. of metallic iron.

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The Honeycroft Rake Ironstone covers a considerable area near Dale, in the same neighbourhood. It contains 32 per cent. of metallic iron. The additional reserve is possibly large but unproved.

The Brown Rake Ironstone, with 18 to 30 per cent. of metallic iron, has a wide extension along the western margin of the coalfield. Here there is probably a large additional unproved reserve.

	Yield per acre. Tons.	Developed area. Tons.	Additional reserve. Tons.
Dale Moor and Civilly Rakes	3,500	8,960,000	13,440,000
Honeycroft Rake Ironstone	6,000	38,400,000	unproved.
Black Shale and Striped Rakes ...	4,000	304,000,000	,,
Brown Rake	2,500	115,200,000	,,
Ironstones of restricted occurrence ...		100,000,000	,,
		566,560,000	13,440,000
		580,000,000	

WARWICKSHIRE.

From notes by W. Gibson.

The White Ironstone, with an average iron-content of 33 per cent. in the raw stone, is estimated to contain 800 tons per acre over an area of 9 square miles, or 4,608,000 tons. Other ironstones, such as the Gubbin, the Black Ironstone and Blue Flats, are capricious in occurrence. The value of the ironstones in the proved extension of the coalfield west of Coventry is not known. They lie at a considerable depth.

NORTH STAFFORDSHIRE.

From notes by H. Dewey.

This is the only coalfield in England in which ironstone is now being extensively raised. It is especially rich in iron ores, still largely used in the manufacture of pig-iron and steel, but not to the extent the great capabilities of the coalfield would lead one to expect. The output decreased from 1,783,000 tons in 1884 to 776,362 tons in 1902 but has since risen.

The ironstones fall naturally into two classes occupying a constant position in the Coal Measure sequence. Those in the Blackband sub-division are laminated ores of the variety known as Blackbands; those below are classed as Clay-ironstones.[1]

Four Blackband ironstones have long been worked in North Staffordshire. The Halfyard, Red Shagg and Red Mine Ironstones are developed towards the central part of the coalfield, but in the southern part the Bassey Mine alone exists. Towards the western margin the ironstones pass into limestones. Some of the estimates made by various authorities appear to have been made on the assumption that the whole coalfield, with an area of 100 square miles, would be productive of ironstone.

[1] 'The Geology of the North Staffordshire Coalfields,' *Mem. Geol. Surv.*, p. 213.

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The *Halfyard or Blackband Ironstone* is worked on a small scale and mixed with the other 'Red Mines' before calcination. It is said to average 37 per cent. metallic iron, phosphorus ·3, sulphates and sulphides 2·0.

The *Red Shagg Ironstone* contains on the average 38·8 per cent. metallic iron, ·4 phosphorus, sulphates and sulphides 2·5. Productive area, 18 square miles.

The *Red Mine Ironstone* is richer in the lower than in the upper part. The averages of the two parts, according to a large number of recent analyses, show: metallic iron, 39·4 to 26·8; phosphorus, ·19 to ·28; sulphur, trace to nil; manganese, 1·23 to·7. Productive area, 18 square miles.

The *Bassey Mine* is the principal ironstone now worked. In the calcined ore the iron-content ranges from 49·5 to 54·5, phosphorus from ·5 to ·7, sulphur up to ·95. Productive area, 28¼ square miles.

The *Burnwood* is a semi-blackband, which passes into a clay-ironstone. In the raw stone the iron-content ranges from 24·9 per cent. in the Central District to 37·79 in the south. Of the clay-ironstones only two bands of irregular occurrence are now being worked, namely the *Cannel Row*, with 57·9 metallic iron, ·83 phosphorus, 1·17 sulphur, 1·83 manganese, in the calcined ore; and the *Pennystone* with 47·85 metallic iron, ·5 phosphorus, ·54 sulphur, in the calcined ore. Productive area of the clay-ironstones, 51 square miles.

In the Cheadle Coalfield the Froghall Ironstone lies near the base of the Coal Measures. It was highly valued for its kindly properties in the smelting furnace, and was so exhaustively mined that except for some patches now being used for making red paint it has been practically worked out. It was deposited in the form of a thin lenticle, under strictly localised conditions. The limits of the lenticle as a workable ironstone appear to have been located on all sides by borings, and such reserves as exist are negligible.

SOUTH STAFFORDSHIRE (WITH WORCESTERSHIRE).

From notes by W. Gibson.

To the south of the Bentley Faults, in an area where the coal and ironstones have been extensively worked, ironstones occur as nodules, cakes or thin bands from 2 to 9 in. thick, and are situated on several horizons from near the base of the Coal Measures to just above the Brooch Coal. Analyses of the ironstones are given in the 'Iron Ores of Great Britain,' *Mem. Geol. Surv.* 1856, pp. 131-164. The lowest ironstones are exhausted and the others have been extensively worked. At the present time the White Ironstone below and the Gubbin Ironstone above the Heathen Coal are the principal stones raised in getting this coal. Small quantities are obtained with the Brooch and the Thick Coal. The output from individual mines is small, not exceeding 200 tons per week.

Within the visible coalfield the bulk of the ironstone has been obtained. About 6,000,000 tons of reserve of Gubbin Ironstone occur in the Rowley Regis District, and some remains to the west

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and east of Dudley and about Netherton. In the concealed coalfield the White Ironstone on the west and the Gubbin Ironstone in the east practically remain untouched.

The Gubbin and Brooch Ironstones are estimated to contain 7,680,000 tons in a developed area of 4 square miles, and the same amount in an undeveloped area of 4 square miles, the yield in both cases being taken as 3,000 tons per acre. The White Ironstone, with a yield of 300 tons per acre on an area of 2 square miles is credited with 3,840,000 tons, making totals of reserves 11,520,000 tons, additional reserves 7,680,000 tons, or 19,200,000 tons in all.

To the north of the Bentley Faults the reserve is estimated at 55,000,000 tons, but ironstones are raised in small quantities and only in conjunction with coal.

SHROPSHIRE.

From notes by H. Dewey.

The iron ores of Shropshire were worked extensively when the furnaces in Coalbrookdale were in operation, but the output now is less than 4,000 tons a year. The ores occur as nodules embedded in shales in the lower part of the Coal Measures, and are better developed in the northern than in the southern part of the coalfield. The principal mines now working ironstone belong to the Lilleshall Company, but the stone is got only in driving roads for coal.

The bands from which ore is raised are:—

The Ragged Robin, the band now principally worked, underlies the Fungous Coal, and is irregular. Metallic iron 32 per cent. after calcination.

The Blackstone used to be highly valued for making 'best best' cold-blast pig-iron. Metallic iron about 38 per cent.[1]

The Yellowstone contains about 30 per cent. metallic iron after calcination.

The Blue Flats and White Flats contain about 36·4 per cent. and about 35·6 per cent. respectively of metallic iron.[1] The White Flats now being worked yield 30 per cent. of iron after calcination.

The Pennystone, which is regarded as the most suitable for cold-blast pig-iron, contains 30-35 per cent. of iron after calcination.

It is estimated that there are 14,000,000 tons of ungotten ore in the northern third of the coalfield. If a similar yield obtains over the whole field the reserves would be about 42,000,000 tons, but a large part is exhausted and most of the area partially worked out. It may be assumed that not less than 30,000,000 tons remain.

FLINTSHIRE AND DENBIGHSHIRE.

From notes by T. C. Cantrill.

These ironstones occur as nodules averaging about 3½ inches in thickness. The more important bands overlie the Llwyneinion

[1] 'Iron Ores of Great Britain.' *Mem. Geol. Surv.*, part 4. 1862.

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Half-Yard, the Wall-and-Bench, and the Ruabon or Lower Yard coals, the first-named being regarded as the best.

The smelting of the local ironstones was carried on mainly at Mostyn, Brymbo, Acrefair near Ruabon, and Ponkey near Rhôsllanerchrugog. The working of ironstone as a separate industry has long been extinct. In 1911 341 tons of ironstone were raised from coal mines in Denbighshire, but in 1915 none was obtained from either Flintshire or Denbighshire. The iron-content is said to have ranged from 20 to 30 per cent.

The estimate of reserves has been made on the assumption that the principal courses of clay-ironstone are available over an area of 10 square miles.

SOUTH WALES AND MONMOUTHSHIRE.

From notes by Prof. T. F. Sibly.

The clay-ironstones of the Lower Coal Series, formerly worked on a large scale, are nowhere mined systematically at the present time. Small quantities (the total output was 15,763 tons in 1915) are raised incidentally at a few collieries in Monmouthshire and East Glamorgan. The nodules or 'balls' of ironstone are brought down, mixed with shale, in ripping the roofs of coal-seams to make the roadways, and in some cases the ironstone is recovered from the rubbish. A little is used locally (at Ebbw Vale), but the bulk appears to be sent to South Staffordshire furnaces.

The ironstones, from Pembrokeshire to Monmouthshire, were analysed when they were being worked and the detailed results were published in 'The Iron Ores of Great Britain,' *Mem. Geol. Survey*, part 3, 1861. They appear to have contained about 34 or 35 per cent. of metallic iron on the average, but Blackbands of occasional occurrence ranged up to nearly 39 per cent. Judging from the specimens analysed, the ores worked in Pembrokeshire contained less iron than those worked in the main coalfield.

As regards reserves the number of courses that exist is so great, and the areas over which they may be productive are so difficult to define, that precise estimates are not possible. The reserves are undoubtedly great.

NORTHUMBERLAND (REDESDALE).

From notes by R. L. Sherlock.

The ironstone worked in Redesdale occurs as nodules embedded in about 30 ft. of shale in the Yoredale Beds, and is closely akin to the clay-ironstones of the Coal Measures. The iron-content appears to reach about 34·86 in a perfectly clean sample of the raw stone.

SUSSEX AND KENT (WEALDEN BEDS).

The working of these ores, which probably commenced in pre-Roman times, ceased in 1828. An account of them is given in 'The Geology of the Weald,' *Mem. Geol. Survey*, 1875, chap.

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xix., etc. No estimate of the amount that has been worked is possible.

FIFE.

From notes by G. W. Lee.

—	Area and yield per acre.	Proved tons.	Probable tons.	Possible tons.
(1) Blackband in Coal Measures, Bogside	95 acres; 5,200 tons	—	494,000	—
(2) Blairhall or Upper Comrie Blackband	150 acres; 3,128 tons	—	468,000	—
(3) Do. do.	400 acres; 3,120 tons	—	—	1,248,000
(4) Lower Comrie Blackband ...	600 acres; 2,080 tons	—	—	1,872,000
	200 acres; 3,120 tons	—	—	
(5) Lochgelly Blackband ...	300 acres; 4,680 tons	—	—	2,402,400
	320 acres; 3,120 tons	—	—	
(6) Blackband below Six-foot Coal	200 acres; 4,420 tons	—	—	884,000
(7) Blackband in roof of Lochgelly Splint Coal	120 acres; 2,080 tons	249,600	—	—
(8) Blackband in roof of Mynheer Coal	47 acres; 1,740 tons	80,000	—	—
(9) Clay-band in roof of Five-foot Coal	129 acres; 600 tons	77,400	—	—
(10) Denhead Blackband in Lower Limestone Group	150 acres; 3,120 tons	—	—	468,000
		407,000	962,000	6,874,400

These ironstones are all in the Limestone Coal Group except the first and the last.

The output of ironstone in Fife was 2,128 tons in 1913, all from Coal Mines.

(1) Worked about 50 years ago with a coal, 2 ft. 2 in. thick, of which it forms the roof.

(2) Exhausted over the more accessible areas.

(3) Westward extension to depth of 200 fathoms. A few boreholes have reached the seam.

(4) Estimates founded on a few boreholes only.

(5) Chiefly near Lochgelly. The estimate includes 624,000 tons for the Cowdenheath district, where mining has just been commenced. Iron in calcined ore 34 to 56·8 per cent.; sulphur, 1·4; phosphorus, 3·9 per cent.

(6) Working from 1870–74. The ore dips to the S.E. and has not been proved.

(7) Small quantities are raised when occasion offers.

(8) Worked when the distance above the coal is not too great. Iron (raw ore), 33·59; manganese, 0·69; sulphur, 0·81; phosphorus, 0·82 per cent.

(9) Taken out with the coal; 600 tons raised in five months in 1917.

(10) Worked long ago at Denhead and Lumbo. Intervening ground not known.

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MIDLOTHIAN.

From notes by T. Robertson.

—	Area and yield per acre.	Proved tons.	Probable tons.	Possible tons.
(1) Great Seam Blackband, Mauricewood	8½ acres; 7,106 tons	—	68,400	—
Do. do.	385 acres; 3,600 tons	—	—	1,410,000
(2) Loanhead No. 2 Blackband	13 acres; 7,281 tons	95,000	—	—
Do. do.	96 acres; 5,200 tons	—	500,000	—
Do. do.	44 acres; 5,200 tons	—	—	228,000
(3) Loanhead No. 1 Clayband and Blackband	12½ acres; 7,281 tons	90,000	—	—
Do. do.	81½ acres; 7,281 tons	—	593,600	—
Do. (Gilmerton)	49½ acres; 9,707 tons	—	480,000	—
Do. (Gilmerton)	58 acres; 9,707 tons	—	—	561,000
Do. do.	43 acres; 7,281 tons	—	—	313,000
Do. do.	260 acres; 4,680 tons	—	—	1,216,800
(4) Gilmerton Blackband in the Lower Limestone Group	116½ acres; 4,072 tons	—	475,400	—
Do. do.	225 acres; 4,072 tons	—	—	917,200
		185,000	2,117,400	4,646,000

All these ironstones are in the Limestone Coal Group except the last.

The output of ironstone in Midlothian in 1913 was 22,903 tons, all from Coal Mines.

(1) Worked out above 100 fathoms; dies out to the north and is of doubtful occurrence to the south and east.

(2) Partly worked out above 200 fathoms; dies out to the north and south, but is good in depth to the east. Iron (raw ore), 23·5; silica, 8·37; alumina, 4·05; sulphur, 1·06; phosphorus, 0·41 per cent.

(3) In the Gilmerton district; dies out to the north and east; much faulted and workings flooded in 1875. In the Loanhead district; partly worked to 200 fathoms; dies out to the south and is unproved to the east. In the Clayband:—iron (raw ore), 34·1; silica, 2·99; alumina, 1·10; sulphur, 0·29; phosphorus, 0·47 per cent. In the Blackband:—iron (raw ore), 29·7, and silica 5·29 per cent.

(4) Abandoned in 1885; much faulted.

AYRSHIRE.

From notes by G. V. Wilson.

—	Area and yield per acre.	Proved tons.	Probable tons.	Possible tons.
(1) Craigmark Blackband ...	700 acres; 3,500 tons	2,450,000	—	—
(2) Plann Blackband	640 acres; 1,560 tons	—	1,000,000	—

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—	Area and yield per acre.	Proved tons.	Probable tons.	Possible tons.
(3) Moncur Musselband	360 acres; 4,000 tons	—	—	1,440,000
(4) Kilwinning Main Coal Ironstone	1,280 acres; 4,500 tons	—	—	5,750,000
(5) Dalmellington and Lugar Blackband	2,620 acres; 5,000 tons	1,500,000	—	6,200,000
(6) Do. do.	5,120 acres; 5,000 tons	3,200,000	—	20,000,000
(7) Logans Bands (calcareous claybands)	7,680 acres; 4,650 tons	—	—	30,750,000
(8) Garibaldi Ironstone (calcareous)	2,560 acres; 2,000 tons	—	—	5,000,000
(9) Dalry Claybaud	640 acres; 4,300 tons	—	3,500,000	—
(10) Do.	11,200 acres; 4,650 tons	—	50,500,000	—
		7,150,000	55,000,000	69,140,000

The first six are in the Coal Measures, the remaining four are in the Limestone Coal Group.

The total output of ironstone from Ayrshire from Iron Mines and Coal Mines was 217,423 tons in 1913.

(1) Has been little worked; depth small over the area considered. Iron, 15·99; silica, 6·43; coaly matter, 50·29; sulphur, 0·95; phosphorus, 0·18 per cent.

(2) Of good quality; a considerable unworked area to the west of Kilmarnock. Iron, 31·5; silica, 2·5; phosphorus, 0·6; sulphur, 0·26 per cent.

(3) A carbonaceous bed associated with a clean coal. Iron, 30·78; silica, 2·5; alumina, 2·70; lime, 82·10; sulphur, 0·37; phosphorus, 0·20; loss on calcining, 44·75 per cent.

(4) Calcareous; abandoned on account of high sulphur-content.

(5) District of Dalmellington and Rankinston; faulted out to S.E. and N.W., mostly unproved to the N.E. Iron, 27·82; silica, 8·88 per cent.

(6) District of Lugar, Old Cumnock and Muirkirk; probably poor to the S.W., very deep to the W., and cut off by a fault to the N. The "proved reserve" lies at less than 300 fathoms deep, the "possible reserve" at 300 to 600 fathoms.

(7) Persistent over a large area, but variable in thickness and quality. Iron, 44·31; silica, 7·91 per cent. for the calcined stone.

(8) Worked as recently as 1914 at Glengarnock. Of good quality but variable. Iron, 47·54; silica, 11·30; sulphur, 0·16; phosphorus, 0·55 per cent.

(9) Worked up to 1897 in the district of Lugton and Caldwell at shallow depth. Uniform in thickness.

(10) Uniform in thickness over wide areas in the districts of Kilbirnie, Lochwinnoch, Glengarnock and Dalry. Iron, 25·7 to 28·89; silica, 7·62 to 9·70; alumina, 5·95 to 4·41; sulphur, 0·23 to 0·08; phosphorus, 0·56 per cent.

CENTRAL COALFIELD (RENFREW, LANARK, STIRLING, DUMBARTON AND PART OF LINLITHGOW).

From notes by M. Macgregor.

The following bands occur in the Coal Measures:—

Crofthead Slaty Blackband at base of Coal Measures.—A coal formerly wrought in several districts, but generally poorly developed or absent. Last worked in 1901.

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Armadale Slaty Blackband, a few feet under Colin Carn Coal.—A local seam not now worked.

Clayband Balls above Ball Coal in the Falkirk, Armadale and Fauldhouse Coalfield—Output in 1913, Falkirk coalfield, about 3,600 tons; Armadale, about 31,000 tons.

Clayband above Mill Coal in Falkirk Coalfield.—Output in 1913, nil; in 1917, 9,333 tons.

Clayband Balls above the Upper Drumgray Coal.—Occasionally worked on a small scale.

Kiltongue Mussel-shale and Ironstone.—The ironstone is thin and poor; the shale above it has been worked locally for oil.

Bellside Blackband.—Local in the Newhouse-Wishaw district. Working long discontinued.

Roughband Clayband above the Virtuewell Coal.—Locally developed; occasionally worked with the coal.

Airdrie Blackband, widely sought after in the past, but none now available. In other districts it exists as a coal (Blackband Coal).

Palacecraig Blackband. Strictly local to Airdrie; now exhausted.

The following table relates to ironstones in the Millstone Grit and Carboniferous Limestone Series:—

—	Area and yield per acre.	Proved tons.	Probable tons.	Possible tons.
(1) Bowhousebog Blackband ...	80 acres; 3,120 tons	—	249,000	—
(2) Curdly Clayband	1 acre; 4,200 tons	—	4,200	—
(3) Black Metals of Kilsyth (= Banton Claybands)	14,640 acres; 4,500 tons	—	—	65,880,000
(4) Do. do.	9,600 acres; 3,600 tons	—	—	34,560,000
(5) Do. do.	10,240 acres; 4,200 tons	—	5,000,000	38,000,000
(6) Do. do.	900 acres; 5,400 tons	—	4,860,000	—
(7) Do. do.	15,360 acres; 4,800 tons	—	—	73,750,000
(8) Johnstone Clayband ..	1,230 acres; 300 tons per inch	—	7,380,000	—
(9) Do. ..	1,000 acres; 300 tons per inch	—	—	6,000,000
(10) Do. ..	1,920 acres; 300 tons per inch	—	100,000	11,520,000
(11) Do. ..	9,600 acres; 300 tons per inch	—	—	51,840,000
(12) Raesgill Claybands... ...	130 acres; 3,600 tons	—	468,000	—
(13) Do.	130 acres; 2,400 tons	—	312,000	—

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—	Area and yield per acre.	Proved tons.	Probable tons.	Possible tons.
(14) Household Claybands	... 5,120 acres; 300 tons per inch	30,000	200,000	36,864,000
		30,000	18,573,200	318,414,000

The first two ironstones are in the Millstone Grit and the last two are in the Lower Limestone Group. The remainder are in the Limestone Coal Group.

The total output of ironstone in the Central Coalfield in 1913, from Iron Mines and Coal Mines, was 349,107 tons.

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(1) and (2) Irregular and only locally workable.

(3) District of Kilsyth, Banton, Nethercroy and Kirkintilloch. A thick constant bed of blaes with bands of ironstone. Iron, 34·75 (calcined, 48·78); silica, 8·26; alumina, 4·78; lime, 3·70; manganese oxide, 1·23; magnesia, 3·74; sulphur, 0·014; phosphorus, 0·42; loss on calcination, 28·50 per cent.

(4) N.W. of Glasgow. A thick and constant bed of blaes with 12 to 14 inches of ironstone.

(5) N.E. of Glasgow. In places 15 to 17 inches of ironstone in 4 to 5 feet of blaes. Development under the Central Coalfield little known and yield per acre theoretical. Iron about 40 per cent.

(6) District of Denny. Generally one seam to 11 to 14 in., with thinner seams close above or below.

(7) District of Denny. The estimate of "possible reserves" relates only to the area covered by the few available boreholes.

(8) Paisley-Johnston district. Seam constant. Iron, 45·88; silica, 12·93; alumina, 8·73; lime, 5·82; phosphoric oxide, 3·05 (calcined ore).

(9) Cardonald and Corkerhill. Seam constant in thickness and character.

(10) Nitshill. Seam constant in thickness and character.

(11) N.W. of Glasgow. The estimate is founded on the supposition that a thickness of 18 in. of ironstone in a 4 to 5 ft. working is constant over the area proved by boreholes.

(12) Carluke district. The upper or 5-ft. working, with about 12 in. of ironstone; locally workable.

(13) Carluke district. The lower or 3-ft. working with about 8 or 9 in. of ironstone; locally workable.

(14) Nitshill and Hurlet district. The ores pass into thin limestones to the N. and N.W.; extension to the E. unknown.

The Main Ironstone of Cadder and the Kilsyth No. 3 Blackband of Dumbreck Colliery is still worked. The output in 1913 from the former was 73,437 tons, and from the latter, 27,806 tons. In neither case are the reserves large. Recently the working of a blackband has been begun at Bo'ness and thin seams of blackband occur in association with workable coals at Giffnock and elsewhere. The well-known Banton Blackband was last worked at Nethercroy in 1914. All of these are in the Limestone Coal Group.

Revision in the Central Coalfield of Scotland.

Braehead and Auchengray, Lanarkshire (Sheet 23).

Mr. Hinxman was engaged for a few weeks during the summer in revising the maps of the Carboniferous area south of the

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Wilsontown fault, between Forth, Braehead and Auchengray (Sheet 23). This revision was necessary to complete the resurvey and description of Area VI. of the Central Coalfield of Scotland.

A complete sequence of the Calciferous Sandstone strata of this region is probably present in the district of Auchengray, there being no evidence of any unconformity between the rocks of that series and those of the Upper Old Red Sandstone along the west side of the North Medwin valley.

A freshwater limestone, regarded as the equivalent of the Burdiehouse seam, occurs close to the surface on the east side of Stallashaw Moss.

The higher seams of the Lothian oil-shales—the Fraser, Raeburn and Fells Shales, are present in the area north of the Wilsontown fault, between Cobbinshaw and Auchengray, and have been worked at Tarbrax. On the south side of the fault the positions of the Fells Shale and Houston Coal have been proved in bores near Ampherlaw and Muirhall; it is therefore possible that workable shales may be present in the ground along both sides of the railway south of Auchengray Station, but there is no evidence to show whether these shales extend westwards beneath the limestones of the Braehead basin.

An interesting feature of the Carboniferous Sandstone in this district is the occurrence, near the top of the Series and 3 to 4 fathoms below the Main Limestone, of a group of clayband ironstones, which were formerly wrought to a considerable extent under the name of the Kilpothall or West Sidewood Ironstones. They appear to be confined to a limited area on the south-east margin of the Braehead basin and thin out rapidly towards the west.

The Carboniferous Limestone rocks of the Braehead district include possibly the whole of the Lower Limestone Group, but the presence of any seam belonging to the succeeding Limestone Coal Group, in the ground south of the Wilsontown fault, cannot be demonstrated.

The Main Limestone and the Coal beneath it were extensively worked in the past along the south side of the basin, but the quarries have long been abandoned. The Raesgill Ironstones of Carluke, which lie between the two lowest Hosie Limestones, were also wrought in past times to the north of Braehead and near East Sidewood; a considerable area of these ironstones is probably available, at no great depth from the surface, to the north of the line of old open-cast workings. The outcrops of the seams within the basin are a good deal interrupted and displaced by faulting.

Refractory Materials.

Fireclay.

Ayrshire.—In last year's Summary of Progress, p. 15, mention was made of a peculiar hard non-plastic fireclay lying immediately above the Millstone Grit Lava Series in North Ayrshire. Near Saltcoats and Stevenston the rock contains a high percentage of alumina and is exceedingly refractory, but as the outcrop is

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traced east towards Kilmarnock the quality deteriorates considerably as is shown by the following tests:—

Saltcoats	Seger cone		36
Stevenston	„	„	35
Smithston	„	„	32
Lugton Water	„	„	31
Annick Water	„	„	29
Fenwick Water	„	„	30–31

Mr. Wilson reports that the clay is now being mined and worked near Saltcoats and Stevenston, and the practical tests to which the finished articles have been subjected show that they are of exceptionally high quality.

Arran.—On the published one-inch Geological Survey map of Arran, volcanic rocks are shown occurring at the position of the Millstone Grit. As the bauxitic fireclay which occurs at this horizon in Ayrshire is now being worked, and may prove to be valuable, a visit was paid to Arran by Mr. Wilson. The presence of a similar seam of clay at this horizon was ascertained.

The section exposed in the Merkland Burn near Brodick Castle is as follows:—

Red fakes and blaes	
Pink bauxitic fireclay	5 ft.
Hardish decomposed red lava	4 „
Soft „ „ „	16 „
Thin red limestone	1 „

The clay is of the same general character as that on the mainland, but is rather harsher to the touch, pink in colour, and contains numerous strings and grains of hæmatite. Tests have shown that it is not so refractory as the fireclay of Saltcoats and Stevenston.

Wigtownshire.—At Low Knockglass, about $1\frac{3}{4}$ miles south-west of Stranraer, a similar fireclay is exposed near the base of a thin series of rocks, apparently of Upper Carboniferous age, resting unconformably on Silurian strata and covered by Permian brockrams and red sandstones. The material is of a pink or lilac colour, like that of Arran, but is rather softer to the touch. At least 3 ft. is seen, but the section must be opened up before the full thickness can be ascertained. Samples have been taken and arrangements made for practical tests of the quality of this clay.

Report on Scottish Occurrences of Felspar.

By Dr. R. Campbell.

Sutherland.—The pegmatites reported on by Mr. Dinham[1] were revisited and additional specimens collected. A thick vein on the south side of the Durness-Rispond road merits attention since it contains less plagioclase and biotite than the normal pegmatites of the Beinn Ceannabeinne area. It forms a conspicuous crag on the hillside just behind the shepherd's house at Ceannabeinne, $\frac{3}{4}$ mile east-south-east of Sangobeag. For a distance of at least 140 yards it maintains an average thickness of over 25

[1] 'Special Reports on the Mineral Resources of Great Britain,' *Mem. Geol. Surv.*, vol. v, 2nd edition, 1917, pp. 1–14.

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feet. It is understood that the Beinn Ceannabeinne property has been leased, and in 1917 several trial-quarries had been opened and the most highly felspathic portions of the pegmatites were being separated by hand-picking.

Other pegmatites were examined in the country to the north of Loch Inchard. Of these the occurrence most likely to prove of economic value is a vertical dyke at Cnoc-an-Tuir about halfway between Rhiconich and Achriesgill. It can be traced from the side of the Kinlochbervie road in an east-south-east direction for 200 yards in a series of knolls. The outcrop is lenticular, varying in width from 20 feet to 35 yards. In the widest portion inclusions of gneiss are rather numerous. Thirty feet may be taken as a moderate estimate of the average thickness of good pegmatite-material. This dyke is a coarse-grained pegmatite showing little sign of crushing. The dominant constituent is pink microcline with which are associated quartz, buff-coloured albite-oligoclase, and a little mica. The microcline and quartz occur partly as a coarse graphic intergrowth, partly as separate crystals, and the latter mineral forms veins up to a foot in thickness. Analyses of the alkali content of the average material of the pegmatite and of the soda spar were made by Mr. Radley; the former yielded K_2O—9·35, Na_2O—2·05, the latter K_2O—2·74, Na_2O—7·13 per cent. The average rock would be classed as a spar of Grade 2; much of the microcline could be separated readily by hand-picking to give a spar of Grade 1; small quantities of the soda spar might also be hand-picked, and might suit the requirements of glass-manufacturers who desire a spar rich in soda. The pegmatite is distant less than 200 yards from the shore of Loch Inchard.

Argyllshire (*Strontian District*).—Numerous dykes and veins of white and pale-pink pegmatite traverse the schists and granites between Ben Resipol and Loch Sunart. They have a general north and south trend and are usually vertical or nearly so; they thicken and thin out rapidly giving characteristic lenticular outcrops. In the limited time at his disposal Dr. Campbell was able to make only a partial examination of these pegmatites, but three occurrences may prove to be of economic value.

(*a*) About ¼ mile north-east of the farm of Ardarie and 4 miles west of Strontian there occurs a dyke of highly felspathic pegmatite in which some years ago two trial quarries were opened for the exploitation of mica. The dyke can be traced for a distance of over 200 yards. Near a small stream, about 80 yards west of the quarries, it has a breadth of about 20 feet with rather numerous inclusions of the country-rock. Southwards it rapidly increases in thickness, and for the last 130 yards of its course, until it is lost under the boggy ground in the direction of Loch Sunart, the outcrop maintains an average width of about 35 feet of coarse pegmatite almost free from inclusions of schist.

The rock is in great part a coarse graphic intergrowth of quartz and pinkish-white felspar. Locally, however, the quartz and felspar occur separately in bands up to 4 feet or more in thickness. The dominant felspar is a pinkish-white microcline-perthite en-

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closing small scales of muscovite. White albite-oligoclase is present in smaller amount. Large plates of muscovite also occur, but are confined to a few definite layers; in one of the quarries two courses of muscovite were noted, one about 10 inches thick, the other ranging from 1 inch to a foot in thickness. Individual books of mica attain a breadth of as much as a foot.

The bulk of the felspar occurs as a graphic intergrowth with quartz and would give a spar of Grade 2. But a very considerable yield of most pure microcline-perthite (with less than 5 per cent. of quartz) might be obtained by hand-picking. A market might be found for the mica and the quartz as well as the felspar. The probable minimum quantity of pegmatite available is estimated as 50,000 tons. The chief difficulty in transport would be in getting the quarried material across the uneven hill-slope to Ardarie. From Ardarie to the shore of Loch Sunart at Camasine is a distance of a little over a mile by road.

(*b*) A dyke of white pegmatite varying in width from 18 to 20 feet, forms a conspicuous feature on the north shore of Loch Sunart on the west side of Point Sron-na-Saobhaidh. Cutting vertically through the schists and trending 10° W. of N. it can be traced up the face of the cliff to the Strontian-Salen road and appears again in a succession of knolls in an oak wood beyond. The rock consists essentially of white felspar (partly microcline-perthite, partly oligoclase) and quartz with subsidiary amounts of muscovite and biotite and an occasional accessory garnet. It has the highly irregular texture characteristic of fine-grained pegmatites, and at the same time shows considerable local variation in the relative amounts of the chief constituents. Both the striated oligoclase and the microcline-perthite are white in colour and it has not been found possible to obtain a satisfactory estimate of the relative amounts of the two felspars. Biotite becomes locally rather abundant in some of the finer-grained parts of the rock, and a few garnet-rich patches have been noted. Such portions form a small proportion of the total rock-mass and could be got rid of by hand-picking. Inclusions of the adjacent schists are so few in number as to be almost negligible.

Little selection would be necessary to obtain iron-poor and alkali-rich material suitable for the enamel industry, but it is doubtful whether spar suitable for extraction of potash could be obtained in any quantity even with careful hand-picking. There is deep water close inshore where the dyke occurs. The estimated probable quantity of pegmatite available without pumping or mining is 100,000 tons.

(*c*) At a point about two miles north-west of Strontian Parish Church and by the side of the old road which leads to the lead mines at Coire an t-Suidhe there occurs an exposure of pegmatite which merits further investigation. The outcrop is about 900 square yards in extent and the rock resembles the Ardarie pegmatite described above. It is distant about $3\frac{1}{2}$ miles from the shore of Loch Sunart.

The Strontian property has been leased by the Scottish Felspar Company, and quarrying operations have already been commenced.

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Banffshire.—Dr. Campbell visited the pegmatite-dykes mapped by Dr. Horne on the Banffshire coast east of Portsoy. The largest of these, and the only one likely to prove of economic value, occurs on the west side of East Head. The dyke is vertical and can be traced almost continuously for about 300 yds. For 80 yds. it forms the face of the 25-ft. beach cliff, trending north-east and south-west. Keeping the same direction it can be followed in a succession of small knolls which rise above the level of that beach until, as the high-water line is approached, it begins to trend north-north-east and south-south-west. At high-water mark the width of the outcrop is 45 ft.; near the south-western end of the dyke it is 25 ft. Further to the south-west isolated knolls of pegmatite appear on the moorland tract between the 100 ft. and 200 ft. contours. These are in alignment with the above dyke and may indicate a prolongation of its course inland under a covering of drift.

The pegmatite is brick-red in colour. It consists essentially of a fine graphic intergrowth of microcline and orthoclase with quartz, with tourmaline, muscovite, biotite, and acid plagioclase as accessory constituents. Of the accessory minerals tourmaline is most abundant, and much of the rock from its richness in that mineral would be unsuitable as raw material for the enamel, glass, and pottery industries. An analysis of the alkali content by Mr. Radley gives K_2O—8·90 per cent., and Na_2O—2·48 per cent.; the rock therefore merits consideration as a possible source of potash.

The estimated minimum quantity of pegmatite available from that portion of the dyke which extends from the 25 ft. beach cliff to high-water mark is 7,000 tons. Assuming that the dyke continues along the line indicated by the isolated outcrops described above, and assuming further that it maintains an average thickness of 18 ft. in its course inland, a much greater quantity, say 50,000 tons, may be available. The dyke is situated less than a mile from Portsoy Harbour and railway station. There is a road to within 500 yards of the outcrop, and a footpath with easy gradient for the remainder of the distance. The path could be converted into a road suitable for carting at very little expense.

Aberdeenshire.—Dr. Campbell also visited the granites of the Peterhead and Tillyfourie districts of Aberdeenshire. He concluded that from the point of view of the present enquiry the rock most likely to prove of value is the red Corrennie granite.

Situated on the south side of the Aberdeen-Alford railway at Tillyfourie Station the Corrennie quarries have been opened on a narrow belt of granite which connects the Hill of Fare granite of Deeside with the Benachie and Cairn William mass to the north. The Corrennie rock is salmon-pink in colour, very highly felspathic, and almost free from ferro-magnesian minerals, which are represented only by an occasional small crystal of biotite. The felspar is mainly microcline and orthoclase, acid plagioclase being subordinate in amount. An analysis of the alkali-content by Mr. Radley shows that the average rock contains K_2O—8·02 and Na_2O—1·37, with a trace of LiO_2.

The Corrennie quarries have been worked for over 20 years by

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Messrs. John Fyfe & Sons, Ltd., and the spoil-heaps would furnish an immediate supply of many thousands of tons. For practical purposes the available supplies may be regarded as unlimited. A steel wire-rope haulage system is used to run the material from the quarries to a siding at Tillyfourie Station, the distance from which to Aberdeen is 24 miles by rail.

Kincardineshire. — Dr. Campbell visited the pegmatites, granites, and felsites on the Kincardineshire coast between Girdleness and Cove Bay. None of the pegmatites is of sufficient thickness to be regarded as of economic value; the granites carry much more biotite than the Corrennie rock. The most promising occurrence from the point of view of the present enquiry is a felsite at the Cave of the Red Rocks. The felsite occurs as a gently inclined sill, intrusive in the gneisses, which dip inland at about 10°. It is seen in continuous section at and near the top of the cliff, following the course of a series of indentations in the coastline for about 700 yds., thinning towards the south and ending abruptly to the north, and maintaining an average thickness of 15 ft.

The rock is a pale brick-red felsite showing scattered small rounded quartz phenocrysts in a fine-grained, compact groundmass. Thin sections show that the dominant felsitic groundmass is uniform in composition, consisting essentially of a microcrystalline aggregate of quartz and orthoclase with numerous scales of muscovite. Ferromagnesian minerals are absent, but their former presence in small amount may be indicated by the occurrence of occasional shreds of limonite. The alkali content of the average rock was found by Mr. Radley to be K_2O—4·67 per cent., Na_2O—3·53 per cent., along with a trace of Li_2O.

For a considerable part of its course the sill forms the summit of the cliff, and is free from, or nearly free from, cover. It is well-jointed, breaking readily under the action of the ordinary denuding agencies into large slabs up to a foot in thickness. The most suitable point for quarrying preparations is about 150 yards from the railway (opposite the farm of Mains) and from the adjoining road which leads to Cove Bay Railway Station, about 1½ miles distant. From Aberdeen the distance by rail is 3 miles.

Samples of the rocks described above have been submitted for trial to various manufacturers of enamel and pottery, and to the Potash Supplies Department of the Ministry of Munitions, for analysis and experiment.

THE MID-SCOTLAND SHIP CANAL.

Much information bearing on the alternative routes of the proposed Mid-Scotland Ship Canal was collected during the year by Mr. Dinham.

In connection with the northern or Lomond Route, some 80 bore-journals were collected, giving a general idea of the nature of the Carse deposits at different points south-east of Stirling, and showing that here rockhead is not likely to be touched except perhaps near Carnock House. A short report also was prepared on the coal-seams in this part of the Stirlingshire coalfield.

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With regard to the Leven Valley branch scheme, the alluvial deposits of the River Leven were examined, and interesting evidence collected regarding the depth of the sub-alluvial valley at Dumbarton. The Vale of Leven occupies the site of what appears in preglacial times to have been a fjord, joining the Clyde on the east side of the Dumbarton Rock, not, like the course of the present river, on the west side. The buried northern slope of the Rock descends, at first almost precipitously, to a small ledge at about 160 ft. below Ordnance Datum, and beyond this it falls more gradually. North-east of the Rock, at a point within 190 ft. of its nearest visible side, the old valley floor reaches a depth of at least 200 ft. below sea-level, the slope therefore being more than 45°.. Nearer its centre it is known to be at least 250 ft. deep, and we may note that the greatest proved depth to rockhead in the buried Kelvin Valley, at Drumry, N.E. of Clydebank, is 240 ft. below O.D. The material with which the Leven fjord is now filled up consists almost wholly of mud, probably largely glacial, running sand and occasional boulders. Only at the top, down to 20 or 30 ft. below sea-level are beds of finer sand, and occasionally gravel, met with; these pass up-stream into distinct fluviatile terraces which tend to coalesce at the mouth of the valley, where they have perhaps been re-sorted by tidal action.

At the northern end of the valley, where the Leven issues from Loch Lomond at Balloch, proof has been obtained that sand and gravel, with finer muddy deposits toward the base, descend to at least 25 ft. below sea-level.

Work was subsequently undertaken on the southern or Kilsyth, so-called 'Direct' Route. This lies almost entirely within the Central Coalfield, and upwards of 250 bore-journals were available for showing the nature of the surface-deposits from Grangemouth to Clydebank. The geological structure and composition of the Carboniferous strata involved were outlined in a short report, illustrated by sections. The following is a summary of the results of the investigation so far as the surface-deposits are concerned.

At the east end of the canal, between tide-marks, old workings in the Grangemouth collieries show that boulder clay extends to 210 ft. below Ordnance Datum. The route at once crosses from the preglacial valley of the Forth into that of the Carron, the rock-ridge between them, here not higher than 100 ft. below O.D., being overlain by boulder clay beneath the Carse deposits of mud and red clay. The greatest recorded depth of the preglacial Carron valley along the route is near Carronbank, where rockhead is not higher than 270 ft. below O.D. Here, and elsewhere in this old valley, the boulder clay under the Carse clays is separated from the rock by about 100 ft. of sandy deposits. Beyond Carron Grange the route runs along the northern slope of the buried valley, and then, crossing to its southern side, leaves both the preglacial and the present-day Carron valleys at a point a little below Bonnybridge. In cutting the canal, rock should first be met with hereabouts, near the farm of Gateside, and is likely to appear thence continuously at least as far as

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Inchterf, between Kilsyth and Kirkintilloch—a distance of 14 miles. Up to Kelvinhead the line runs in the valley of the Bonny Water, the rock-bottom of which is not certainly known to be anywhere deeper than 15 feet above O.D. The buried channel which runs along this valley is not in general as broad as that of the Carron, and appears to be especially constricted at Wyndford Lock, and again at Craigmarloch, where its visible sides, formed by a dolerite sill, are less than 200 yards apart. It is evident that the proposed canal, with gentle curves of 2 miles radius, will not coincide everywhere with the centre of the buried valley, and will therefore intersect varying thicknesses of the surface-deposits, consisting mainly of sand and gravel, and ranging along this stretch from 5 and over 100 feet. The rock-sides will in general consist of sandstones and shales, but whinstone (quartz-dolerite) is met with at Craigmarloch and, in the northern bank at least, should line the canal for half a mile in the neighbourhood of Auchinstarry. The canal then crosses the dolerite sill at Auchinvole, and near this spot will locally have to be cut down at least 130 feet into whinstone rock.

West of Auchinvole House the route enters the great buried channel of the Kelvin, and rockhead rapidly descends. The mansion is said to be built upon trap, while less than 100 yards away the alluvium is reported to be 120 feet in thickness. Rockhead at this last place is consequently only about 30 feet above O.D.; at Twechar it is probably the same, and descends to sea-level S.W. of Inchterf. From here to Torrance direct evidence is scanty, but it is unlikely that rockhead will rise higher than 20 feet above O.D., while it may descend as low as 40 feet below that level. The surface-deposits consist generally of sand and gravel, though "brown till and boulders" have been recorded opposite Kirkintilloch. At Meadowbank rockhead rises to 60 feet above O.D., but rapidly plunges to 170 feet below beyond Torrance Bridge. From this point rockhead will lie for some distance well below the bottom of the canal, being about 200 feet below sea-level at Buchleyford. Here the route begins to leave the Kelvin buried channel and passes obliquely across its south bank, rockhead accordingly climbing rapidly to 80 feet above Ordnance Datum, half a mile N.E. of Killermont House. At this point the surface-deposit is only 16 feet thick. Rockhead then gradually falls to 18 feet above O.D. at South Westerton, and from Cloberhill onwards to the Clyde is not likely to occur again in the cutting. The surface-deposits throughout this final stretch consist mostly of soft clay with some sand and gravel.

III.—PETROGRAPHICAL WORK.

Reports have been furnished to other Government Departments on various matters of economic or military importance, including world-sources of radium, chromite, cobalt and selenium, and on sources of potash-felspar in the Colonies. A number of specimens of German concrete from Flanders was submitted by the War Office to the Geological Survey for examination with a view to the identification of the pebbles and rock-fragments of which the concrete was composed. The result went to show that all the

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pebbles could be matched in the Rhine gravels, but that there was a notable absence of Belgian rocks. Some of the rock-fragments were recognised as having come from a German source. The Report has been published in Foreign Office Papers, 'Miscellaneous, No. 2 (1918).' Subsequently specimens of cement were submitted; these were compared, as regards their microscopical and chemical characters, with a large series of British cements, and the results communicated to the War Office.

Specimens from the South Sandwich, the Falkland and South Shetland Islands, and Graham Land have been reported on for the Colonial Office. An improvement in the construction of aeroplane-compasses has been devised for the Admiralty by Dr. Thomas with the co-operation of Mr. Radley. The description of silica-rocks, hearth-sands and dolomites for the first of the volumes on Refractory Materials, has been completed.

IV.—CHEMICAL WORK.

In connection with the work on Refractory Materials, 53 further analyses have been completed by Mr. Radley. One mineral from California has been completely analysed for the Scientific and Industrial Research Department, and some specimens from the Falkland Islands examined for the Colonial Office, as regards their value as fuel or as sources of oil. The following estimations of alkalis in some Scottish igneous rocks have been made:—

Lab. No.	550	551	552	553	554
K_2O ...	8·90	2·74	9·35	4·67	8·02
Na_2O ...	2·48	7·13	2·05	3·53	1·37
Li_2O ...	not found	not found	not found	trace	trace

Anal. E. G. Radley.

Lab. No. 550 (Slice No. 19628). **Vertical dyke in schists, Banffshire coast**; west side of East Head and three-quarters of a mile N.E. of Portsoy. 1-inch map 96.

Lab. No. 551. One of the constituents of a pegmatite-dyke. Roadside at Cnoc-an-Tuir, between Rhiconich and Achriesgill, N.E. shore of Loch Inchard, Sutherland. 1-inch map 113.

Lab. No. 552. Vertical dyke in gneiss. Same locality as Lab. No. 551.

Lab. No. 553 (Slice No. 19625). Sill intrusive in gneiss. Cave of the Red Rocks, 1½ miles N.E. of Cove Bay Railway Station, Kincardineshire. 1-inch map 77.

Lab. No. 554 (Slice No. 19626). Granite-intrusion, Corrennie Quarry at Tillyfourie Railway Station, Aberdeenshire. 1-inch map 76.

V.—PALÆONTOLOGICAL WORK.

England and Wales.

The fossils collected during the year were obtained principally from borings. The identification of the Mesozoic fossils from deep borings in Kent has been completed by Dr. F. L. Kitchin and Mr. J. Pringle.

A large number of the specimens presented by the Geological Society has been transferred to the Museum-cases; among many

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type-specimens are included fishes from the Old Red Sandstone. Many drawings of fossil fishes, prepared under the supervision of L. Agassiz, and now in the possession of the Geological Society, have been examined by Mr. Allen and found to include a large number of unpublished figures, to the originals of which Agassiz gave names without publishing adequate descriptions. A considerable number of these specimens have been identified in the above-mentioned collection, and have been placed in the Museum for reference.

The most notable donation received during the year is a valuable collection of invertebrate fossils from the Coal Measures, presented by the late Capt. L. Moysey, R.A.M.C. This includes arthropods of much rarity and interest, some of which have been figured and described.

The following specimens in the Museum have been figured and described:—

In the Quarterly Journal of the Geological Society, Vol. LXXII.

By Dr. A. Smith Woodward, F.R.S., V.P.G.S.

Edestus newtoni *A. S. Woodw.*, pl. i, p. 1.

By H. Bolton, Esq., M.Sc., F.R.S.E., F.G.S.

Pseudofouquea cambrensis (*Allen*), pl. iv, figs. 4, 5, text-fig. 6, p. 59.

By Stanley Smith, Esq., D.Sc., F.G.S.

Phillipsastraea hennahi (*Lonsdale*), pl. xxii, figs. 1–4, p. 288.

In the Transactions of the Royal Society of Edinburgh, Vol. LI.

By F. R. C. Reed, Esq., M.A., Sc.D., F.G.S.

Obolus audax *Reed*, pl. i, figs. 7, 8, p. 798.
Paterula balclatchiensis *Dav.*, pl. i., f. 19, p. 800.
Rhinobolus? balclatchiensis *Reed*, pl. ii, f. 7, p. 802.
Acrothele medioradiata *Reed*, pl. iii, figs. 20, 21, p. 813.
Orthis (Harknessella) vespertilio *J. de C. Sow*, pl. xi, figs. 3, 4, p. 862.
„ ? nina *Dav.*, pl. xi, f. 8, p. 863.
Strophonella penkillensis *Reed*, pl. xviii, f. 14, p. 900.
Triplecia craigensis *Reed*, pl. xx, f. 5, p. 908.
Mimulus? incertus *Dav.*, pl. xx, f. 22, p. 911.
Clitambonites complectens (*Wiman*), *var.* albida *Reed*, pl. xxi, f. 20, p. 916.

Scotland.

No systematic palæontological work was done, but fossils were collected from the cores of borings and from sections the stratigraphical position of which was in doubt. On the evidence thus obtained it was possible to base important conclusions.

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VI.—MUSEUM OF PRACTICAL GEOLOGY.

The Museum remained closed, except for special enquiries Work has been continued upon the Report on Silica-rocks ganister, hearth-sands and dolomite.

A considerable number of specimens of British Iron Ores wa sent in by the Survey Field Staff.

Among the donations, attention may be drawn to the presen tation by the late Captain L. Moysey, R.A.M.C., referred to on p. 40.

List of Donations during the year 1917.

Abbott, Dr. G., M.R.C.S.—Five specimens of Concretionary Magnesian Limestone from Fulwell Hill, Roker, and Carley Hill, Durham. (Two figured: *see* 'Nature,' February 8th, 1917.)

Acton, A., Esq.—One specimen of fused silica-brick from Wrexham, and one specimen of colour-marking in Millstone Grit, from Flintshire.

Bell Bros., Ltd., Messrs.—Iron Ore, core of Main Seam, from Kilton Mine.

Bolckow, Vaughan & Co., Ltd., Messrs.—A series of specimens of Yorkshire Iron Ores.

Burls, H. T., Esq.—(*See* Petroleum Research Dept.)

Burr, Dr. M.—A specimen of Caucasian Oligocene with shells, and Tertiary shells from the Corinth Canal.

Colonies, The Under-Secretary of State for the.—Five Rock-specimens, possibly from the South Sandwich Islands; also twenty-nine rock- and mineral-specimens from the South Shetland Islands and Graham Land.

Congleton Silica Brick & Ganister Co., Ltd., Messrs., The.—Samples of Dry Ganister, Silica Sand, Fireclay, Silica-rock and Millstone Grit.

Craven, C. S., Esq., M.Inst.C.E.—Eighteen Mesozoic fossils from Bamba, on the Niger, East of Timbuctoo.

Crookshank, Lieut.-Col. A. A., R.E.—Two teeth of *Odontaspis elegans* Ag., from the Landenien? of N.E. France.

Davies, Messrs. T. J., & Co.—A series of samples of Sleeves, Nozzles, Stoppers, etc.

Delaney, Messrs. J., Ltd.—Dolomite from Threshfield, Yorkshire.

Fox, Roy & Co., Messrs., Ltd.—A sample of enamel made from Meldon Stone.

Frodingham Iron Company.—Eight brachiopods and lamellibranchs from the Northampton Sands of Woolsthorpe, Grantham.

Garwood, Prof. E. J., F.R.S.—Twenty-seven specimens of the Pre-Cambrian Rocks of Herefordshire, Radnorshire and Shropshire.

Girty, G. H., Esq.—Five specimens of *Diaphragmus* from the Upper Mississippian of Muskingum Co., Ohio.

Greenwood, F., Esq.—A specimen of Graphite from Borrowdale, Cumberland.

Gwersyllt Silica Brick Co., Ltd.—Four samples of Silica Bricks.

Hall, Lieut. T. C.—One specimen of diabase dyke from the Old Shaft, Callow Hill, Minsterley, Shropshire.

Hallimond, A. F., Esq.—One fused Silica Brick from Hutton, West Witton, Durham; also three specimens from the furnace-bottom in the Malleable Steel Works, Stockton-on-Tees.

Hutchinson, Dr. A.—One limestone-specimen from the Limestone Quarries, Burlescombe, Devon.

Jenkin, Capt. C. J., R.E.—Nineteen plants from the Coal Measures, near St. Omer, France.

King, Capt. W. B. R.—A fragment of *Inoceramus* and specimens of Foraminifera from the Dièves (Lower Turonian) of Souchez, Northern France.

Marriott, Major, R.A., D.S.O.—A crystal of Jarrowite from the River Clyde.

Ministry of Munitions of War (through A. E. Russell, Esq.).—Five specimens from Nickel and Arsenic Mine, Talnotry, Kirkcudbrightshire.

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MOYSEY. CAPT. L., R.A.M.C.—Two specimens of Chalk impregnated with Cement from Upstreet Colliery Sinking, Kent; also a large series of fossils, mostly from the Coal Measures, including figured and described specimens.

NEALL, J. A., ESQ.—An ammonite from Malreward, Somerset.

NOBLE, CAPT. A. H.—Sixteen igneous rocks from Mexico.

OSMAN, C. W., ESQ.—Three specimens of inclusions in granite from near Chagford, Dartmoor, Devon.

OSWALD, DR. F., F.G.S.—A geological Model of Nimrud Volcano, Armenia; scale one inch = one mile.

PEDDLE, C. J., ESQ., M.Sc., F.G.S.—Samples of glass made from Muckish Mountain, Lynn, Aylesbury, Huttons Ambo and Fontainebleau Sands, together with specimens of the sands.

PERKIN, DR. F. M., Ph.D., F.I.C., F.C.S.—Specimens of Geyserite from Stadur Reykjanes, S.W. Iceland.

PETROLEUM RESEARCH DEPARTMENT (PER H. T. BURLS, ESQ.).—Specimen of core of Kimmeridge Clay with fossils from boring No. 1 at Holme, and Kimmeridge Clay with fossils from Smith's Pit, West Winch, south of King's Lynn.

ROUTLEDGE, S., ESQ., M.A.—Eight Rock-specimens from Socorra Island, and eleven Rock-specimens from Pitcairn and Easter Islands.

RUSSELL, A. E., ESQ.—(*See* Ministry of Munitions of War.)

RUTHERFURD, W. G., ESQ.—A series of Agates mounted as brooches, to illustrate the production of artistic effects by the selection of suitable natural stones; also a large collection of cut and polished Agates from New Zealand, Australia, Scotland and other parts, together with a number of cut and rough opals; also a specimen of Florentine inlaid work.

SHERBORN, C. D., ESQ.—A large specimen of Tin Stone from the South Crofty Mine, Camborne, Cornwall.

TATHAM, CAPT. ATHOL.—Five specimens of Mollusca from Cretaceous rocks in the Menabe District, West Coast of Madagascar.

TOWNLEY, MISS.—One *Caninia cylindrica* E. & H. from the Carboniferous Limestone of Sligo.

WALFORD, E. A., ESQ.—One *Neaera* and one *Cyathophora bourgueti* (Defr.) from Sharp's Hill, Hook Norton.

WILLIAMS, S., ESQ.—Two specimens of Riebeckite Rocks from Nigeria.

WILSON, A., ESQ.—Six specimens of Quartz from the Carrock Fell Mines, Troutbeck, Cumberland.

VII.—MAPS AND MEMOIRS, ETC., PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

ENGLAND AND WALES.

(a) One-inch Maps (New Series).

(Colour-printed, price 1s. 6d. each.)

Sheet 100, Sheffield. (Temporary Edition.)

A colour-printed Drift Edition of the following Sheet has been issued in place of the hand-coloured edition:—

Sheet 62 (Old Series 93 N.W.). Harrogate.

(b) Six-inch Reference Maps.

The following 27 standard copies of six-inch quarter-sheets have been made from the field-copies, and are available for reference:—

Westmorland, 28 N.W., N.E., S.W., S.E.; 35 N.W., N.E., S.W., S.E.; 38 N.W., N.E., S.W., S.E.; 39 N.W., N.E., S.W., S.E.

Yorkshire, 265 N.W., N.E.; 277 N.W., N.E., S.W., S.E.; 285 N.W., N.E., S.W., S.E.; 297 N.W. (Yorks. part only).

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II.—MEMOIRS.

PUBLISHED MEMOIRS.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1916, pp. 56, text-figures 3. Price 1*s.* 6*d.*

Special Reports on the Mineral Resources of Great Britain. Vol. IV.—Fluorspar. Second Edition. By R. G. Carruthers, R. W. Pocock, B.Sc., and D. A. Wray, B.Sc.; with contributions by H. Dewey and C. E. N. Bromehead, B.A., pp. 39, text-figures 2. Price 9*d.*

The Geology of the South Wales Coalfield. Part IV.—The Country around Pontypridd and Maesteg. (Explanation of Sheet 248). Second Edition. Revised by W. Gibson, D.Sc., and T. C. Cantrill, B.Sc., pp. 160, plate 1, text-figures 6. Price 3*s.* 6*d.*

The Geology of the Country around Bournemouth. (Explanation of Sheet 329.) Second Edition. By H. J. Osborne White, F.G.S., pp. 79, text-figures 13. Price 2*s.*

SCOTLAND.

I.—MAPS.

(a) One-inch Maps, Colour Printed.

Sheets 36, 60. Solid and Drift Geology. Price 2*s.* 6*d.* each.

(b) Six-inch Reference Maps.

The following copies of six-inch maps have been completed and deposited in the office for reference. These are whole sheets, each consisting of four quarter-sheets, except when otherwise stated :—

Banff, 5 S.W., S.E.; 6 N.W., S.W.; 11, 12 N.W.
Inverness 9, 10, 140, 142 S.W.
Nairn, 5.
Ross, 57, 89, 90.
Sutherland, 29, 38.

II.—MEMOIRS.

PUBLISHED MEMOIRS.

Summary of Progress for 1916. See above.

The Economic Geology of the Central Coalfield of Scotland. Description of Area II. (Denny and Plean; Banknock; Carron and Grangemouth; Cumbernauld; Castlecary and Bonnybridge; Falkirk and Slamannan). By L. W. Hinxman, B.A., F.R.S.E., C. B. Crampton, M.B., C.M., E. M. Anderson, M.A., B.Sc., and M. Macgregor, M.A., B.Sc.; with contributions by the late C. T. Clough, LL.D., F.R.S.E., pp. 92, plates 9; text-figures 4. Price 4*s.* 6*d.*

The Economic Geology of the Central Coalfield of Scotland. Description of Area VIII. (East Kilbride and Quarter). By R. G. Carruthers, F.G.S., and C. H. Dinham, B.A., pp. 55, plates 2, text-figure 1. Price 2*s.*

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APPENDIX I.

ON A DEEP BORING, NEAR MARKET WEIGHTON.

By W. Gibson, D.Sc.

Several trial borings for coal have been made south of the Humber, even though the cover of Triassic and Permian rocks was known beforehand to be of considerable thickness. North of the Humber, and approaching Market Weighton, the Jurassic and Cretaceous formations show a marked attenuation, and borings near Selby prove the Coal Measures to extend north of the Ouse. If, then, the Trias and Permian had also proved thin, the Coal Measures might have been accessible near Market Weighton.

The present explorations were carried out in 1912-14 by Messrs. J. and T. Mitchell, to whom we are indebted for access to the cores and journal and for permission to publish this account.

Two borings were put down, of which the first was abandoned at about 1,000 ft. depth. The second hole was commenced a few yards away and was carried down to a depth of 3,100 ft. The site is 440 yds. north of the Reformatory School, 2½ miles south-west of Market Weighton, on the north side of the Market Weighton Canal (6-inch Ordnance Map, Yorks, 209; 1-inch New Series, Sheet 72, Ed. 1903), at a height of 30 ft. above O.D. It is 14¾ miles N.E. of a boring for coal at Barlow (The Concealed Coalfield of Yorkshire and Nottinghamshire, *Mem. Geol. Surv.* 1913, pp. 72-73) and 17 miles nearly due north of a boring near Scunthorpe, which is said to have proved Coal Measures (P. F. Kendall, *Rep. Brit. Assoc.* for 1910, p. 608). Continuous cores were drawn from the first hole; in the second, percussion drilling, with occasional recourse to a diamond crown, was adopted. Below 2,100 ft. almost continuous cores were obtained, and at 3,100 ft. a core, 3¼ inches in diameter was produced. No appreciable dip could be determined and, since the deflection of the hole was shown to be slight, the thickness of 3,100 ft. proved in the boring can be taken as the true thickness.

The following account is abstracted from the boring-journal:—

	Thickness. Ft.	In.	Depth. Ft.	In.
Superficial, 2 ft.				
Clay and stones	1	6		
Gravel	–	6	2	–
Keuper Marl, 634 ft.				
Red sandy marl and mixed marl	78	–	80	–
Red sandy marl with grey plies [skerries]	30	–	110	–
Red marl with gypsum and red marl	59	–	169	–
Conglomerate	8	–	177	–
Red marl with some gypsum and bastard sandstone	36	–	213	–
Conglomerate	4	–	217	–
Red and variegated marl, with hard bands and some gypsum	145	–	362	–
Gypsum	–	4	362	4
Blue and red marl	5	–	367	4
Gypsum	–	1	367	5
Variegated marl with bands of gypsum	75	1	442	6
Blue variegated marl	1	6	444	–
Variegated marl with gypsum	161	–	605	–
Red variegated marl	31	–	636	–

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	Thickness. Ft.	In.	Depth Ft.	I
Keuper Waterstones, 68 *ft.*				
Grey sandstone	14	–	650	
Red sandy marl	6	–	656	
Soft grey sandstone	20	–	676	
Red and grey sandstone	28	–	704	
Bunter Sandstone, 1,425 *ft.*				
Red sandstone	218	–	922	
Variegated sandy marl	66	–	988	
Red sandstone	186	–	1,174	
Red sandstone with marl partings	631	–	1,805	
Conglomerate	25	–	1,830	
Red sandstone with marl	25	–	1,855	
Conglomerate with limestone	24	–	1,879	
Red sandstone	157	–	2,036	
Mottled marl	22	–	2,058	
Red sandy marl	15	–	2,073	
Red sandstone	12	–	2,085	
Red sandstone with marl	37	–	2,122	
Soft grey sandstone	1	–	2,123	
Red sandstone with marl	6	–	2,129	
Upper Permian Marl, 212 *ft.*				
Red mottled marl with gypsum	173	–	2,302	
Red marl with blue stones [rock salt]	39	–	2,341	
Upper Permian Limestone, 141 *ft.*				
Limestone [pale grey and cream-coloured]	20	–	2,361	
Limestone with anhydrite	9	–	2,370	
Limestone [pale limestone with casts of lamelli-branchs]	112	–	2,482	
Middle Permian Marl, 29 *ft.*				
Rock salt	23	–	2,505	
Dark red marl with anhydrite	4	6	2,509	6
Dark mottled marl	1	6	2,511	
Lower Permian Limestone, 589 *ft.* 3 *in.*				
Limestone [giving off a strong smell of petroleum] ...	48	9	2,559	9
Limestone with anhydrite	17	6	2,577	3
Grey limestone	169	–	2,746	3
Brown and grey limestone with anhydrite	133	–	2,879	3
Grey anhydrite	221	–	3,100	3

End of Boring.

Summary.

	Thickness. Ft.	in.
Superficial...	2	–
Keuper Marl	634	–
Keuper Waterstones	68	–
Bunter Sandstone	1,425	–
Upper Permian Marl	212	–
Upper Permian Limestone	141	–
Middle Permian Marl	29	–
Lower Permian Limestone	589	3
	3,100	3

The small thickness of the superficial deposits is in agreement with neighbouring tracts (J. W. Stather, *Rep. Brit. Assoc.* for 1907, pp. 325-328).

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The Keuper Marls in the first boring consist of a homogeneous mass of red variegated marl, streaked with gypsum and with occasional interbedded thin layers of hard, red and grey sandstones (skerries). The so-called 'conglomerates' of the second boring are likely to have been red marl containing rounded concretions of lime ('race'). A thickness of 634 ft. was proved, but the boring entered the marls about 200 ft. below their summit.

Below the Keuper Marls the coarse, light-grey sandstones, 68 ft. thick, agree with similar beds that occur beneath the Keuper Marl of Nottinghamshire and are there classed with the Keuper Waterstones.

Below the Waterstones the boring traversed red sandstones down to 2,129 ft. depth, bands of red marl, one of them 22 ft. thick, occurring at intervals. Pebbles of quartz and other rocks are absent, though pellets of red marl give the appearance of conglomerates on the outside of cores. This may be the explanations of the 'conglomerate' at 1,830 ft., but it is difficult to assign that at 1,879 ft. to any part of the Bunter formation as revealed in borings north of the Humber. The sandstones are all fine-grained, becoming more loamy and micaceous in the lower part. They are chiefly red in colour, and grey sandstones, such as occur in several borings—notably at Strensall, in the Vale of York—are absent.

The Upper Permian Marl is considered as commencing at the first band of red marl with gypsum, but there is little difference in appearance between these marls and those in the Bunter. Brine issued from the boring about the depth of 2,302 ft., and stringers of rock-salt were found in the cores below this depth.

The Upper Permian Limestone consists chiefly of pale cream-coloured limestone, with occasional bands of fine grey limestone. A few obscure casts of shells were obtained by Mr. Manson.

The Middle Permian Marls are much thinner than those found in other borings of the Humber region, but resemble them in character and in the local development of a bed of rock-salt.

The Lower Permian Limestone varies much in texture and colour. It is usually compact, unfossiliferous, and contains large clots of amorphous anhydrite. This mineral also occurs separately as crystals, sometimes arranged in a spherulitic manner. The solid compact mass, 221 ft. thick, of grey and bluish-grey anhydrite, from 2,879 ft. depth down to the bottom of the boring, is exceptional. At Selby and Barlow borings, bands of anhydrite, 18 and 20 ft. thick, occur in the Upper Permian Marls, and a thin band in the Upper Limestone, but in the Lower Limestone there are only interspersed anhydrite and gypsum. At Market Weighton 368 ft. of limestone lies above the anhydrite, and as a greater thickness of limestone is found in other borings to the south-west it is possible that the anhydrite was deposited at Market Weighton while limestone was laid down to the south-west in the manner suggested for the thick mass of anhydrite at Hartlepool (C. T. Trechmann, *Quart. Journ. Geol. Soc.*, vol. lxix, 1913, pp. 184-218). The boring, however, fails to reach the

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base of the Permian, and the anhydrite may represent the basement shales found in borings to the south.

The results obtained by the Market Weighton boring dissipate any hopes that the Triassic and Permian formations thin away north of the Humber; on the contrary, each of these formations, when compared with other borings to the south, has shown a marked expansion. It might be suggested that the Trias and Permian rocks of Market Weighton owe their thickness to their occupying a local depression, but the easterly slope of the floor, as determined in borings to the south-west of Market Weighton, is sufficient to carry the floor 100 ft. below the bottom of the borehole.

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APPENDIX II.

On a Boring in Deep Drift at Gosmore, near Hitchin, October, 1917.

By A. Strahan, Sc.D., LL.D., F.R.S.

New Series Ordnance, One-inch Sheet 221. Old Series Geological, Sheet 46 S.E.

Long. 0° 16′ 30″. Lat. 51° 55′ 42″.

Above O.D. 270 ft.

Communicated by Messrs. Le Grand and Sutcliff.

	Thickness. Ft.	Depth. Ft.	
Dug well	44	—	
Drift, clay and stones	16	60	
Flints and large stones	20	80	water-level varies
Gravel and sand	6	86	
Sand	11	97	
Clay with grains of chalk	29	126	
Hard rock	8	134	
Sandy clay	6	140	
Sand and flints	12	152	
Sand, clay and stones	34	186	
Sand and veins of chalk	12	198	
Grey clay or chalk	20½	218½	
Clay, sand and stones	1½	220	
Clay (light-blue)	to 30	250	

No water was obtained from the lower part of the borehole, but a sufficient supply for the farm was got from the gravel at a depth of 77 to 97 ft.

A small specimen of the light-blue clay, from a depth of 220-250 ft., consisted of a uniform pale-bluish grey silty clay, free from large grains.

The boring is situated about 40 ft. above the outcrop of the Melbourn Rock, and, allowing 170 ft. for the thickness of the Lower Chalk, the base of the Chalk might have been expected at a depth of 210 ft., *i.e.*, at a height of 60 ft. above O.D. An old boring in Hitchin, however (between the Priory and the Church), is described as having reached the base of the chalk at a depth of 229 ft.,[1] or 9 ft. below O.D., and as having passed through 214 ft. of Gault into Lower Greensand. The identification of chalk in this old boring was attended with some doubt.

If the estimate of the position of the base of the chalk is correct, the bottom of the new borehole must be 36 ft. below that base; if the old record is to be trusted it must be about 20 ft. below that base. No chalk in place has been traversed in the boring, but the clay at 220-246½ ft. might be Gault, though its appearance is more that of a stoneless band in boulder-clay.

The borehole is situated near the western margin of the drift-filled channel described by Mr. W. Hill in the *Quart. Journ.*

[1] 'Geology of the London Basin,' *Mem. Geol. Surv.*, 1872, pp. 453, 454.

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Geol. Soc., vol. lxiv., 1908, p. 8. It lies between Ransom's Brick Yard, where the Gault was reached under 340 ft. of Drift, at 68 ft. below O.D., and a boring made by the Hitchin Joint Hospital Board, where chalk was reached under 159 ft. of Drift, at 159 ft. above O.D.

The Henlow boring, described by Mr. Hill in the *Proc. Geol. Assoc.*, vol. xxiii, 1912, p. 223, and in the Summary of Progress for 1912, *Mem. Geol. Survey*, 1913, p. 89, is situated in the same drift-filled channel, but about 5¼ miles N.N.W. of Gosmore. A red mottled clay, the origin of which is unknown, was found at Henlow. Its absence is to be noted in all the borings farther south.

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APPENDIX III.

On a Deep Boring for Coal at Kelham, Nottinghamshire.

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The boring at Kelham was made in the years 1908-12 in search of coal. The site is on the left bank of the Trent, 1½ miles W.S.W. of the Midland Railway Station at Newark, in the New Series 1-inch Map, Sheet 126, and the Old Series Geological Map, Sheet 70. The surface of the ground is about 40 feet above Ordnance Datum, and the dip of the strata was inappreciable.

The Coal Measures were reached at a depth of 1,401 ft. from the surface, and the strata down to that depth have already been described in 'The Water Supply of Nottinghamshire' (*Mem. Geol. Surv.*), 1914, p. 81.[1] The remainder of the section is now made known by permission of the Coal and Iron Development Syndicate through Mr. J. Ford, M.I.Min.Eng., F.G.S., under whose superintendence the boring was made. The details supplied by Mr. Ford are supplemented by observations (in square brackets) made by Dr. Gibson during the progress of the operations.

Kelham Borehole.

From a section communicated by Mr. J. Ford (partly abridged as regards the strata between the coal seams).

	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Superficial Deposits; Triassic and Permian rocks...	1,401	–	1,401	–
Coal Measures—				
Shale with ironstone, and thin sandstones ...	44	6		
Coal and dirt...	1	6		
Shale	33	6		
Sandstone	8	–		
Shale	18	–		
Coal 3 ft. 2 ins. Parting 2 ins. Coal 1 ft. 0 ins. Parting 3 ins. Coal 1 ft. 11 ins.	6	6	1,513	–
Shale	26	6		
Coal	–	4		
Shale with ironstone	18	2		
Coal and fireclay	1	6	1,559	6
Shale, etc.	32	9		
Coal	1	–	1,593	3
Fireclay and shale with ironstone	53	3		
Bind, fireclay and shale	33	6		
Coal	1	7	1,681	7
Fireclay	10	5		
Coal	1	2	1,693	2

[1] The thickness of one of the sub-divisions of the Pebble Beds in this account is wrongly given as 338 feet. It should be 438 feet.

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	Thickness. Ft.	In.	Depth. Ft.	In.
Fireclay and shale	22	4	1,715	6
Dark-greenish rock [igneous rock]	77	5	1,792	11
Fireclay and shale with ironstone	26	–		
Coal	–	9		
Fireclay	13	7		
Coal	–	5		
Black shale	–	2		
Coal	–	6	1,834	4
Fireclay and shale with ironstone	80	–		
Shale and bind	82	8		
Coal and bat	1	2	1,998	2
Fireclay, shale and bind	140	5		
Coal	–	6	2,139	1
Shale and bind	64	5		
Shale with ironstone	92	2		
Coarse grey sandstone	2	3		
Fireclay	11	11		
Dark shale [*Lingula, Pterinopecten*]	3	4		
Coal [Alton Coal or Halifax Hard Mine]	1	5½	2,314	7½
Sandstone, stony bind, fireclay and shale	39	4½	2,354	–
[Millstone Grit]—				
Hard whitish sandstone	12	4	2,366	4[1]
Sandstone with iron-pyrites and band of shale	10	1	2,376	5
Yellow coarse-grained sandstone, yielding saline water	20	2	2,396	7
Hard grey sandstone	3	4	2,399	11
Conglomerate with crystalline pebbles [quartz]	1	–	2,400	11
Sandstone	–	9	2,401	8
Conglomerate	–	3½	2,401	11½
Dark shales	26	3½	2,428	3
Dark shales with stone-bands	5	–½	2,433	3½
Fireclay	4	–	2,437	3½
Grey sandstone } yielding oil	2	–	2,439	3½
Coarse brown sandstone } yielding oil	13	1	2,452	4½
Coarse conglomerate } yielding oil	–	4	2,452	8½
[Millstone Grit or Carboniferous Limestone Shales?—]				
Dark shales and bands	30	2½	2,482	11
Hard sandy bind with ironstone-bands	7	10	2,490	9
Dark shale	7	6	2,498	3
Conglomerate	–	7	2,498	10
Hard white sandstone	1	6	2,500	4
[Carboniferous Limestone Shales—]				
Black shale	2	–	2,502	4
Hard sandy bind with ironstone	14	8	2,517	–
Black shale	15	–	2,532	–
Hard white stone [Crowstone]	10	6	2,542	6
Dark shales with iron-bands [*Lingula* and Goniatites]	56	1	2,598	7
Conglomerate	1	–	2,599	7
Sandstone	–	8	2,600	3
Limestone, coralliferous and yielding hot water	18	9	2,619	–

The lowest strata, 18 ft. 9 in. thick, were found by Dr. Gibson to consist of calcareous and fossiliferous shales with an earthy limestone, penetrated for 1 ft., at their base. The limestone yielded a fragment of a compound coral. The 'hard-white

[1] From here downwards the section is given in full detail as communicated.

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stone' at a depth of 2,542 ft. 6 in. was a siliceous band or 'Crow-stone,' characteristic of the upper part of the Carboniferous Limestone Series.

The igneous rock met with at a depth of 1,715 ft. 6 in. is described in 'The Concealed Coalfield of Yorkshire and Nottinghamshire' (*Mem. Geol. Surv.*), 1913, p. 58. It may be classed as a teschenite, with some unusual characters.

The section proved in the borehole admits of more than one interpretation, and the identity of the seam proved at 1,513 ft. is in doubt. By Messrs. Ford M. Deacon, and C. R. Hewitt it is regarded as the Top Hard Seam, but the fact that the Alton Coal was identified only 800 ft. below it suggests the possibility of its being a seam much lower in the series than the Top Hard.

The Lower Coal Measures extend to a depth of 2,354 ft., and no more than 148 ft. of strata at most can be classed as Millstone Grit, or scarcely an eighth part of the thickness of this subdivision at its outcrop, upwards of 26 miles farther west.

It is necessary, therefore, to infer that the boring passed through at least one fault. The identification of the so-called Top Hard as one of the lower seams and a supposition that the Millstone Grit is faulted against the Carboniferous Limestone Shales, would account for the observed facts, and there is independent evidence that the borehole is situated on or near a line of fault which throws the beds down to the S.W. An alternative supposition is that attenuation on a rapid scale takes place eastwards both in the Middle Coal Measures and in the Millstone Grit.

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1918.

I.—*INTRODUCTION.*

By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S., Director.

Work in connection with the War.

The cessation of hostilities on the signing of the Armistice on 11th November, 1918, leads to the expectation that the normal work of the Geological Survey may be resumed at no distant date. At the commencement of the War the three districts of (1) Denbighshire and Shropshire, (2) Warwickshire and Staffordshire, (3) London and the South-East of England, were in hand. In 1915 the work in the London and South-East district was suspended and a series of Special Reports on the Mineral Resources of Great Britain was commenced. In 1916 work on the other districts was suspended, and the energies of those members of the staff, who had not gone on military or other duty, were concentrated thenceforward upon problems connected with the War, or upon matters of immediate economic importance. The present time seems suitable for placing on record the work of the Survey during the period of hostilities.

The history of each member of the staff, who was accepted for military or other duty with the Forces, is given in the following list:—

Geologists.			
Dixon, E. E. L.	... Lieutenant	Royal Garrison Artillery (T.)	—
Bailey, E. B.	... Lieutenant	Royal Garrison Artillery	Mentioned in despatches. Military Cross. Chevalier Legion of Honour. Croix-de-Guerre with Palm. Twice wounded.
Anderson, E. M.	... Sapper	... Royal Engineers ...	... Wounded.

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Geologists.			
Carruthers, R. G.	Lance-corporal	Tank Corps	—
Bromehead, C. E. N.	Private	Duke of Cornwall's Light Infantry	Wounded.
Cunnington, C. H.	Lieutenant	Machine Gun Corps	Invalided out of Army, Oct., 1917. Died 26 April, 1918.
Richey, J. E.	Captain	Royal Engineers	Military Cross. Wounded.
Eastwood, T.	Lance-corporal	Royal Army Medical Corps (Sanitary Section)	—
Pocock, R. W.	Lieutenant	Royal Garrison Artillery	—
King, W. B. R.	Captain	Royal Welsh Fusiliers (attached to Engineer-in-Chief, G.H.Q.)	Mentioned in despatches. O.B.E.
Wray, D. A.	Lance-corporal	Royal Army Medical Corps (Sanitary Section)	—
Read, H. H.	Corporal	Royal Fusiliers	—
Whitehead, T. H.	Captain	Suffolk Regiment (transferred to General List and attached to Intelligence Corps)	Wounded.
Evans, R. du B.	Captain	Shropshire Light Infantry	Wounded. Prisoner of War
Assistant Clerk.			
Frisby, P. A.	Captain	Suffolk Yeomanry	—
Fossil Collectors.			
Eckford, R. J. A.	Corporal	Royal Scots and Royal Engineers (Special Brigade)	Wounded.
Manson, W.	Deck Hand	Royal Naval Reserve (T.)	—
Haldane, D.	Lieutenant	Royal Scots	—
General Assistants.			
Rhodes, J.	Corporal	Royal Air Force	—
Stewart, A. P.	Private	Royal Scots	—
Attendants.			
Morgan, S.W.	Reg. Qrtr.-Mstr. Sgt.	London Regiment (London Irish Rifles)	—
Couper, G. L.	Corporal	Royal Engineers (Carrier Pigeon Service)	—
Hepple, D. W.	Private	18th Hussars	Wounded. Prisoner of War.
Draughtsmen.			
Torkington, G. G.	Private	Cameron Highlanders	Wounded.
Bruce, W. G.	Lance-Corporal	Royal Engineers (Field Survey Battn.)	—
Trowbridge, H. G. S.	Bombardier	Royal Field Artillery	—
Kidd, J.	Corporal	Royal Engineers	—
Labourers.			
Wheaton, E.	Sergeant	3rd Hussars	—
Brooker, J. F.	Corporal	King's Own Scottish Borderers	—

The first of the economic investigations to be taken in hand were those required for the preparation of the 'Special Reports the Mineral Resources of Great Britain.' These amounted, fact, to a stock-taking of our home-resources of all minerals

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of economic value. By the end of 1918 seven volumes had been published, and for five of these second editions had been issued. Two were passing through the press, and six volumes on iron-ores, besides other Memoirs on lead-mining, etc., were in an advanced stage of preparation. The demand for these reports leads to a belief that they have met more than a temporary want, and that they will be of lasting value provided that they can be kept up to date.

Of the other activities of the staff during the War, some have been mentioned in previous 'Summaries of Progress,' but many have been hitherto regarded as confidential. The following list includes the more important services which have been rendered to other Government Departments during the period of the War, in connection with matters arising out of the War:—

Notes on the obtaining of drinking-water at short notice in the Chalk and Tertiary strata on the Western Front.

Pamphlet on 'Sources of Temporary Water Supply in the South of England and the Neighbouring Parts of the Continent.' In this connection W. B. R. King was detailed subsequently from the Staff to serve as Geologist on the Western Front.

Preparation of a Geological Map of Belgium on the scale of 1 : 160,000.

Report on the geological character of the ground in Belgium and the North of France and a detailed account of existing water-supplies.

Consultation on water-supply in Gallipoli. This led to three Geologists of the staff (C. H. Cunnington, R. W. Pocock, T. H. Whitehead) being detailed for geological work in Gallipoli.

Report on sources of road-metal in France.

Consultations on the making of tube-wells and the use of sand-screens in boreholes.

Report on water-levels in Chalk.

Preparation of sets of characteristic fossils for use at the Western Front.

Transference of a set of Geological Maps of Belgium on the scale of 1 : 40,000 from the British Museum to the Museum of Practical Geology, and of the Museum of Practical Geology set to the Western Front.

Consultations on the construction of seismographs for locating camouflets.

Report on German concrete from the Western Front, and on the source of the rocks used in it.

Report on German cement from the Western Front.

Preparation of a Geological Map and Section of Le Cateau battlefield.

Preparation of a Geological Map and Section of the Aisne battlefield.

Report on suitability of sand on the Western Front for making concrete.

Report on squeezing-out of clay in dugouts.

Report on water-supply in islands in the Firth of Forth.

Report on methods of tunnelling in Chalk.

Report on the cause of sores on the hands of tunnellers at the Western Front.

Three maps of the World showing sources of economic minerals.

Report on Mineral Resources of Austria-Hungary.

Report on wolfram ores in England.

Report on materials suitable for points and cups of aeroplane-compasses.

Reports on selection of quartz-crystals for Anti-Submarine Division of the Admiralty.

Examination in France of a consignment of quartz-crystals from Madagascar and reporting on same.

Superintendence by the Petrographer of the examination and selection of quartz-slabs by officers of the Anti-Submarine Division.

Report on proposed Mid-Scotland Ship Canal.

Report on a prize-cargo.

Report on borings for oil at Scremerston.

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Consultation on coal in Asia Minor.
Report on suitable valleys for airship-sheds.
Report on sources of radium, uranium-ores, pitch-blende and carnotite.
Report on caves for storage in England.
Collecting and reporting on Scottish fireclays.
Report on occurrences of magnesite at home and abroad (enemy countries excluded).
Report on occurrences of iron-pyrites in the United Kingdom.
Consultation on British phosphates.
Reports on borings for oil in Kimmeridge Shale.
Reports on occurrences of potash-felspar in Great Britain and on the suitability of some Scottish felspars for the manufacture of enamelled ware.
Consultations on sites for aerodromes.
" " munition-factories.
" " shell-store.
Report on decline in output of lead-ore in Great Britain.
Report on sources of selenium.
Report on fluorite and Iceland spar.
Consultation on potash in Alsace.
" " limestone suitable for certain purposes.
" " " for carbide manufacture.
Report (preliminary) on iron-ore reserves in Britain.
Correspondence on obtaining mica from Australia.
Report on underground caves for storing valuables, works of art, etc.
Correspondence on brine at Middlesbrough.
Report on Brown Coal near Cologne.
Macadam-supply on part of Western Front.
Short report on rocks near Archangel as a source of water.
Report on ornamental stones for cemeteries, and inspection of quarries in the Pas de Calais.
Search for potash-bearing rocks in North Wales.
Visiting and reporting on borings for oil by Messrs. Pearson & Son.
Report on occurrence of oil-gas in Gibraltar.
Report on sources of zircon.
Report on use of hexahedric crystals of iron-pyrites by the Germans.
Summary of analyses of British Iron-ores.
Maps showing Mineral Resources of British Empire.
Seven Maps showing localities and output of economic minerals in the United Kingdom.
Reports on borings, water-supplies and drainage, for several camps, aerodromes, etc., in England, Wales and Scotland.
Report on Geology of Gallipoli.
Report on oil-shale resources in Scotland.
Reports on the geology of the Scottish Highlands in conuection with water-power resources.
Consultations on the geology of certain districts suitable for small holdings in Scotland.
Report on mineral resources along suggested new railways in Scotland.
Report on limestone and marl for agricultural purposes in Scotland.

OIL-SHALE RESOURCES OF SCOTLAND.

In the 'Summary of Progress' for 1917, estimates were given of the resources of ironstone in Great Britain, and on two occasions estimates of the coal-resources of Scotland have been drawn up by Royal Commissions. It seemed desirable to frame an estimate of the oil-shale resources of Scotland on similar lines. Dr. Flett reports that the work of estimating areas and calculating thicknesses of the seams from the numerous bore-journals preserved in the Scottish office, was entrusted to Mr. E. M. Anderson, Dr. G. W. Lee and Mr. C. H. Dinham. In each case the revised six-inch geological maps were the basis adopted for the measurement of areas, but information obtained since the maps were published has rendered possible some corrections. By multi-

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plying the area over which a seam occurs by its average thickness and its mean specific gravity, figures were obtained which indicate the total maximum amount of oil-shale available, in the present state of our knowledge.

In these estimates all substances except oil-shale have been excluded, though oil can be obtained, and has been produced in Scotland on a small scale, from cannel-coal, torbanite or boghead, parrot-coal and parrot-shale, peat and ironstone-shale. As regards the thickness and quality which render a shale workable, it was decided to adopt as a standard the conditions which existed in the Scottish oil-shale industry during the ten years preceding the War. Accordingly, shales less than 3 ft. in thickness have been excluded, except in the few cases where their high quality or other favourable conditions have proved them to be of practical value. Also those areas have been excluded where the oil-shale, though present, is known to be of no practical value.

A rough approximation only to the amount of oil likely to be obtained from the oil-shale reserves by distillation is possible. A shale yielding a large quantity of ammonia sulphate can be distilled at a profit, even though it produces only 19 gallons of crude oil per ton. The richest shales yield 60 or 70 gallons per ton. In the Reports of the Mining Inspectors (Home Office) of recent years, 25 gallons of oil per ton is given as the average figure.

As regards depth, 300 fathoms has been taken as the present limit, for it happens, from the geological structure of the shale-fields, that the oil-shale resources below that depth are not large and would not greatly affect the totals obtained. Moreover, there are no bore-records which can serve as reliable indications of the occurrence, thickness and quality of these deep-seated shales. The limit has hardly been reached by the deepest shale-mines.

The figures are tabulated under the two headings, 'Proved and Probable Reserve' and 'Possible Reserves.' Those areas are regarded as 'proved' in which oil-shales are or have been worked on a commercial scale, and in which borings have shown that the shales maintain a workable condition. 'Probable areas' are those in which bores have established the presence of the shale in satisfactory thickness, and in which the geological structure is favourable, having regard to the absence of igneous intrusions with their injurious effects upon the shale.

Areas regarded as 'Possible Reserves' are those in which there are few or no bores, but where, on geological considerations, the shale may be expected to occur within 300 fathoms from the surface, and where there is no reason to doubt that it is of workable thickness and quality. Where the shale is likely to have been 'burnt' by igneous masses, or where it is suspected to be thin or of unworkable quality the whole area has been excluded. In framing estimates of possible reserves accuracy is impossible; the figures depend to some extent on the individual judgment of the geologist who takes the investigation in hand.

The number of shale-seams that have been worked in Scotland is considerable. Nearly all of them lie below the Scottish Carboniferous Limestone. The Torbanehill Boghead, the Levenseat Shale

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and the Kiltongue Shale lie above the Limestones, but have not been worked for many years. The principal shales are, in order from above downwards, the Raeburn, Mungle, Fells, Broxburn, Champfleurie, Dunnet, Camps and Pumpherston Shales. Of these seams, the more important, such as the Broxburn, Dunnet and Pumpherston may form a series many feet in thickness, which is separated into bands of good oil-shale with barren shale or blaes between, and each band may have a separate designation. In no district are all the shales present in workable development; often at the horizon of an oil-shale only a carbonaceous shale or shaly blaes is met with. The horizon is generally recognisable in the bores by the presence of some equivalent bed, or the oil-shale may be there but too thin to work. Oil-shales seem to be much more variable than coal-seams in these respects. It is noteworthy also that they do not pass laterally into coal-seams, but into dark carbonaceous shales yielding little oil.

Each of the important oil-shales is confined, as regards its maximum development in thickness or quality, to one or more areas, and in no one area is it usual to find more than three or four of the oil-shales in satisfactory condition. The numerous masses of intrusive igneous rock that have been injected into the oil-shale measures of the Lothians have destroyed a vast quantity of oil-shale by a process of subterranean distillation, and unfortunately the principal oil-shale seams—the Broxburn, Dunnet and Pumpherston—have all been extensively subjected to this action. Practically all areas where igneous intrusions are known to occur on or near the horizon of an oil-shale, have been omitted from the estimated reserves.

Other factors, not geological, affect the estimates of workable reserves. A shale that was unworkable before the war may, by changed commercial conditions, prove to be of value. As an example, the Pumpherston Shales, which are comparatively poor in oil but rich in ammonia, were once practically valueless, but now are of great importance. The future of oil-shale mining in Scotland would seem to depend principally on two factors—the rates of wages and the prices obtained for oil-shale products (oil, paraffin wax and sulphate of ammonia)—and any changes in these will directly affect the magnitude of the payable reserves of oil-shale.

Since 1873 the output of oil-shale from Scottish mines has been reported each year in the Home Office Returns. From 1873 to 1917, inclusive, it amounted to 89,401,981 tons, or, say, 90 million tons. The rise of Scottish oil-shale mining dates approximately from 1862, when the Torbanehill Mineral was exhausted, and an allowance of ten million tons is more than sufficient to cover all mining before 1872 and also the output for 1918 (not yet published). This gives 100 million tons as approximately the amount of shale that has been mined. To this must be added the amount lost in working from a variety of causes, say, 20%, or 20 million tons; giving a total of shale mined 120 million tons.

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The estimated reserves for the oil-shale fields are as follows:—

	Proved and probable. Tons.	Possible. Tons.
Midlothian	163,497,000	356,120,000
Linlithgowshire	416,539,000	371,211,000
Lanarkshire	16,730,000	67,000,000
Peebles-shire	5,120,000	28,020,000
Fifeshire		61,440,000
	601,886,000	883,791,000
Deduct amount already worked as above	120,000,000	
Total still available	481,886,000	

At present the output is approximately 3 million tons a year. Adding 20% for loss in working we get 3,600,000 tons as the yearly depletion of reserves.

This indicates 133 years as the duration of these Proved and Probable Reserves at the present rate of working. The Possible Reserves, if they all proved available would last for about 245 years under the same conditions, giving for all reserves a possible duration of 383 years. These figures which, of course, make no pretence to exactitude, may be compared with Mr. J. S. Dixon's estimate that the total available quantity of coal in Scotland in seams over 24 in. in thickness would maintain the present output for approximately 315 years.

II.—FIELD WORK.

POTASH-BEARING ROCKS IN NORTH WALES.

In the latter part of 1917 inquiries were addressed to the Geological Survey by the Controller of the Potash Production Department (Ministry of Munitions) with a view to ascertaining what rocks in North Wales contained sufficient potash to be worth a trial in cement-manufacturing. It was proposed to deliver to an important cement-works at Ellesmere a quantity of felspar containing not less than 6% of potash. In the process of cement-making the potash would be obtainable as a by-product. The questions addressed to the Geological Survey related to the known or possible occurrences of potash-bearing rocks in readily-accessible parts of North Wales, and also to the occurrences of rocks rich in soda but free from iron, and of rocks rich in alumina and free from iron. From a consideration of the specimens and analyses in our possession, it became clear that it would be necessary to make further examination of likely rocks in the field, to collect specimens from suitable sites, and to have special analyses made. The igneous rocks were regarded as the only probable source of potash in sufficient quantity, and as a first step in the search for potash the occurrences of soda-felsites and other rocks known to be poor in potash were ruled out. The field-work was further narrowed by consideration of transport. Finally it was arranged that the work of examining sites and collecting specimens should be carried out by Dr. A. H. Cox for the Geological Survey, and that he should co-operate with an officer of the Ministry of Munitions who would consider possibilities of trans-

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port, etc., from the localities selected. This work was carried out in July, 1918.

The specimens collected included:—

3. Rhyolite. Conway Mountain; roadside, quarry opposite Conway Morfa, worked by Conway Corporation.
4. Banded rhyolite. Conway Mountain; roadside, quarry west of Corporation quarry.
5. Blue rhyolite. } Conway Mountain. Conway Stone quarry worked
6. Creamy rhyolite. } by North Wales Granite Co. (Messrs. Brookes, Halifax.)
7. Green felsite, intrusive. Penmaenbach, roadside, west side of intrusion.
8. Banded granophyric felsite, intrusive. Penmaenbach, roadside, centre of intrusion.
9. Nodular rhyolite. Conway Mountain, old quarries on ridge.
12. „ Deganwy, Bryn-gosol Farm.
13. Porphyritic granophyre. Llanbedrog Point, near Pwllheli, worked by Cambrian Granite Co.
14. Dark granophyre. } Gwylwyr Quarry; roadside, 1 mile N.E. of Nevin,
15. Light granophyre. } worked by Penmaenmawr and Welsh Granite Co.
16. Granophyre. Middle quarry, Porth Nant, Nant Gwyrtheyrn, Llithfaen, worked by Kneeschal Lupton.
17. Granophyre. Trevor Quarry, Rivals, worked by Penmaenmawr and Welsh Granite Co.
18. White felsite. Roadside, 1 mile E. of Llithfaen.
20. Dust from dark granite-porphyry. Girn Ddu near Clynog, worked by Enderby and Stoney Stanton Granite Co.
21. White rhyolite. 6th milestone, roadside, S.W. side Llyn Padarn, Llanberis.
22. Blue rhyolite. Above Tunnel; roadside, S.W. side, Llyn Padarn, Llanberis.
23. Mixed rhyolites. Careg-yr-Undeb; roadside, S.W. side, Llyn Padarn, Llanberis.
26. Microgranite. Mynydd Mawr intrusion, lower crags N.E. of Llyn Cwellyn.
37. Pandy ash. Glynceiriog, worked by the Welsh Silica Co.

Specimens were also collected from various shales, and from the mica-schists of Anglesey, as follows:—

31. Mica-schist. Roadside quarry, ¼ mile E.S.E. of Gaerwen Station, Anglesey.
32. Mica-schist (fine-grained). West of Monument, Llanfair P.G.
33. Mica-schist (coarse-grained). Quarry, west end of Menai Bridge village.
2. Slates below volcanic series, east side of Penmaenmawr intrusion.
24. Purple slate. Glyn-rhonwe Quarry, Llanberis.
25. Blue slate, Llanberis Quarries.
27. Arenig slates. Porth Dimdde, Aberdaron.
29. Ashgillian shale. Old quarry, above Deganwy.
35. "White Shale." Coal Measures, Delph, Ruabon, worked by Wyndham and Phillips.
39. Bala shales. Roadside, ¼ mile S. of Glynceiriog.

For aluminous rocks low in iron, specimens were collected from the Coal Measure shales of Ruabon and Buckley.

From the specimens five were selected by the Potash Production Department of the Ministry for examination of the alkali-contents, and the following results were obtained:—

Sample.	K_2O Per cent.	Na_2O Per cent.
21	4·29	2·06
26	3·48	5·77
12	2·91	0·48
17	3·56	5·89
31	2·00	3·19

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Having regard to the low potash-content of these five, it was not regarded as necessary to have the other samples analysed. Further, it was found by tests that the hardness was a serious factor in the matter of output by the grinding plant. The three factors of low potash-content, hardness and distance from the Works did not suggest that the inquiry was worth pursuing further at the present time.

COPPER AND ARSENIC.

With a view to continuing the series of 'Special Reports on Mineral Resources,' inquiries into the resources of copper and arsenical ores were made in Cornwall and Devon by Mr. Dewey. Arsenical ores had hitherto been regarded as by-products, but the use of arsenic in some war materials has led to a sudden increase in demand and price. The two districts of Camborne-Redruth and Kit Hill-Calstock practically yield the entire output. Near Calstock, mines formerly worked for copper-ores left arsenical pyrites behind, and the stopes as well as the dumps are now being exploited for the ore. The reserves appear to be large.

Copper-ores are steadily diminishing in output, and the reserves are approaching exhaustion. A few tons, under 100 per annum, of copper-precipitate is being recovered from mine-drainage and dump-drainage waters, especially at the Levant Mine, St. Just, and the Devon Great Consols Mine near Calstock.

The output of the wolfram remains steady and depends upon the systematic development of the lodes. At East Pool the Rogers Lode maintains its richness, and has been proved recently at South Crofty. The recent fall in the price of wolfram may retard further rapid development.

SALT.

In the course of the year an investigation into all sources of salt in Great Britain was commenced by Dr. Sherlock, with a view to producing a 'Special Report.' The existence of rock-salt in the Keuper Marl of Cheshire, Shropshire, Staffordshire, Somersetshire, Lancashire, Yorkshire, and the Isle of Man, and in Permian rocks in Yorkshire, has long been known. The object of the investigation was to record the extent of these salt-beds, so far as it had been proved, the methods of working them, either by mining or the pumping of brine, and to ascertain what occasion exists to extend these methods into newly-proved ground. That the reserves are ample for all requirements, and that the output could be greatly increased, admits of no doubt.

The output of salt in 1913 is given in the Home Office Statistics as 2,247,758 tons (including 43,321 tons for Ireland), of which 214,573 tons were mined as rock-salt, the rest pumped as brine. An increase in output would depend upon the expenditure, which has to be kept at the lowest possible figure to render profitable the working of so low-priced a commodity as salt. Cheapness of working depends upon the existence of natural brine-runs, or upon the possibility of creating artificial brine-runs, a dry 'rock-head' being regarded as valueless. In Cheshire surface-water is turned

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into the old workings, which form convenient underground reservoirs; in other cases the strata overlying the salt-beds yield sufficient fresh water to keep a brine-run going when communication has been established by borings. The water quickly assumes the necessary condition of complete saturation, and its circulation in the salt-bed becomes freer as solution proceeds.

Among the more recently-discovered localities for rock-salt, mention may be made of a district E.N.E. of Northwich, and of an area at Heatley, near Lymm, in both of which the beds of salt are thick. A salt-bed proved in the borehole at Market Weighton, described in the Summary of Progress for 1917, pp. 42-45, has not yet been developed.

The possibility that salts of potash may occur in the brine or at the top of the salt-beds has been drawn attention to. Analyses have so far shown that these salts exist only in traces.

CANNEL IN GREAT BRITAIN.

The utilisation of cannel and other substances associated with coal-seams as a source of oil having been the subject of much discussion during the later stages of the War, the existing records of cannel-occurrences were published in Vol. VII. of 'The Special Reports on Mineral Resources of Great Britain.' It was understood that the account was preliminary, and that the quantity of cannel available, its value for the purpose named, and the possibility of raising, separating and treating it profitably, remained to be ascertained. As a fact, cannel, of late years, has been generally regarded as a waste-product, detrimental to the value of any coal-seam of which it forms part.

In order to make these investigations, the collieries in which the principal occurrences of cannel had been reported were visited: those in Cumberland by Mr. Smith, Northumberland, Durham and Yorkshire by Mr. Bromehead, Nottinghamshire, Derbyshire, Leicestershire, Warwickshire and North Staffordshire by Dr. Gibson, Lancashire by Mr. Smith and Mr. Pringle, South Staffordshire by Mr. Dewey, and North Wales by Mr. Pringle. The results of the inquiries will appear in a second edition of the volume referred to above, but it may be stated now that they do not point to the possibility of cannels furnishing more than a trifling addition to the oil-supply. A seam of cannel always takes a lenticular form, limited to a small definable area, ranging from a few acres to upwards of 30 square miles, and the most valuable of these lenticles have already been approximately exhausted. The possibility of raising, separating and treating the cannel as a profitable undertaking depends upon circumstances. In some cases the cannel, occurring, as it frequently does, at the top of a seam of coal, has to be left as a roof, or a heavy expense in timbering has to be incurred. Generally, the profit in the undertaking would depend also upon the value of the coke, and in this respect cannels are disappointing. The ash-content is usually high, especially in the impure cannels and 'canneloid' substances that have been suggested for experiment.

The mining of cannel in England and Wales, therefore, is not regarded as a sound commercial proposition, except so far as

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regards the small quantities that can be separated cheaply and used for special purposes, such as the enrichment of gas.

In Scotland a similar investigation is being carried on by Dr. Lee, with the assistance of other geologists. He furnishes the following preliminary account of the results:—

Many seams of cannel were worked in Scotland in the early days of the gas-industry, when a high illuminating gas was in demand, but of recent years they have been almost completely neglected, except where they occur as thin bands in workable seams of coal or ironstone. At Lochgelly in Fife the Upper Five Feet Seam and at Wellesley Colliery, Fife, the Pirnie or Earl David's Parrot were being mined in 1917 and sent to gas-works and oil-works in Scotland. Cannel is also being worked at Loanhead, near Edinburgh, where it forms part of the No. 1 and No. 2 Ironstone Seams. In a number of Scottish coal-mines cannel is being worked and sold with the coal with which it is associated, but it is not generally regarded as improving the value of the coal, though in blast-furnaces, gas-works and for steam-raising, the disadvantages are not so great as to preclude its use in certain proportions. In other cases where cannel is mined as part of a coal-seam it is picked out and sent to gas-works and oil-works. Occasionally it is used for building underground packs, or is cast back into the waste of the mine.

As cannel is not distinguished from other varieties of coal in the Statistics it is impossible to give the output. It is certain, however, that there is very little mining for cannel by itself. It is, in fact, regarded as an inferior variety of coal which was rather avoided by the mining engineer under the conditions which existed in the coal-trade before the war.

The number of seams containing cannel that have been worked is large. Many of those which were well known in the early days of the gas-industry, when cannel was in demand, were worked out and little information can be obtained regarding them, except from old reports. As sources of cannel in the future they are not likely to be of importance. Moreover, the cannel-rib varies greatly in thickness and may pass into ironstone. The correlation of the cannel-seams, especially those of the outlying fields like Muirkirk, Campbeltown and Douglas, is difficult. Some are recognised over large areas, such as that in the Splint Coal of Lanarkshire, and the Kiltongue Musselband and Cannel; others, though comparatively thick, cover only a small area, like the Earl David's Parrot of Fife or the Cannel Seam of the Douglas Castle Colliery. The following list contained the principal occurrences, arranged according to the coalfields in which they are found:—

FIFE.

Calciferous Sandstone Series.—A few thin seams of cannel of poor quality occur in these strata. Near West Pitcorthie, north of Anstruther, a compound seam of true oil-shale, blackband-ironstone and parrot-coal, 10 to 13 in. thick, was worked for a short period about the year 1870, and yielded about 20 to 25 gallons of oil per ton.

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Lower Limestone Group.—A band of cannel 5 in. thick usually accompanies the Blackband Ironstone Seam of Denhead, near St. Andrews.

Limestone Coals Group.—Borings through the lower part of the group, below the position of the Dunfermline Splint Coal have shown the occasional presence of thin seams of cannel associated with workable coals.

One of the lowest workable seams in the series was worked long ago at Drumcarrow, 4 miles S.W. of St. Andrews. The thickness was said to be 16 in. Another seam low down in the series occurs in the small Rameldry basin, near Kettle. Its thickness is given as 4 ft. in the Geological Survey Memoir on Central and Western Fife (p. 125), but in one locality at least it is known to have lost its volatile matter through the action of igneous intrusions.

The Glassee Coal, which is generally a household- or a steam-coal, contains, in the Lochgelly district, from 14 to 21 in. of cannel which is separated and sent to gas-works.

The Lochgelly Parrot Coal contains intercalations of cannel occasionally up to 3½ ft. thick, but as a rule 1 to 10 in. The yield of oil is about 34 gallons per ton. The Swallowdrum Coal of the Dunfermline district often passes into cannel, but is mostly worked out.

Over most of the Lochgelly field the Lochgelly Ironstone is a compound seam of blackband-ironstone and shale (oil-shale). The shale varies up to 16 in., and where richest has given 32 gallons of oil per ton.

The Inzievar Blackband Ironstone, workable only in the extreme west of Fife, near Oakley, is also associated with a cannel a few inches thick.

Upper Limestone Group.—A well-known cannel-seam extends from the extreme west of Fife, where it goes under the name of Cadell's Parrot, to the Lochgelly field where it is known as the Lochore Parrot. It was fairly extensively wrought until the middle of the last century at Oakley and at Lochore. At Lochore the seam varied from a few inches up to 2 ft. 2 in. and contained ironstone. There may be not inconsiderable reserves. In the Oakley district the indications are that the seam is largely wrought out.

The Capeldrae Parrot Coal, not far below the position of the Calmy Limestone, has long been known as a first-class cannel. It is essentially developed in the Capeldrae-Lochore basin, and was systematically worked in the latter half of the last century. The more readily accessible portions are supposed to be worked out, but many of the pits were abandoned before exhaustion on account of difficulties due to water. The seam consisted of two leaves, up to 1 ft. 6 in. and 1 ft. 8 in., respectively, of different quality, the best giving on distillation from 70 to 81 gallons of oil per ton.

The position of the Capeldrae Cannel seam has economic value in only one other district in West Fife—namely, at Oakley, where it is known as Overton or Oakley Parrot, and was wrought extensively.

Coal Measures.—The Lower Dysart Coal contains a band of cannel varying in thickness from 0 to 6 in. It is rich in oil

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of good quality, up to 92 gallons per ton, but the band could not be worked independently of the coal, which is of inferior quality.

At Westfield, north of Auchterderran, an oil-shale occupies a position probably corresponding to the Lower Dysart Coal. The shale is from 2 ft. 4 in. to 3 ft. 9 in. thick, forming the base of a seam of common coal. It was worked for oil-making for a few years in the 'sixties, and again in the 'eighties, yielding from 18·5 gallons to 30 gallons per ton. This seam may possibly extend over the whole of the Kinglassie field, an area of about 3 square miles.

The Pirnie or Earl David's Parrot occurs near the middle of the Coal Measures of Fife and covers 3 to 4 square miles between West Wemyss and Leven, dipping under the Firth of Forth. The thickness varies between 1 ft. 2 in. and 4 ft. 6 in. The quality is generally good, the yield of oil varying from 28 to 74 gallons per ton, with from 20 to 56 lbs. of ammonium sulphate. It was worked at Pirnie from 1864 to 1868 and retorted for oil at Methil. There are probably considerable reserves left, but they cannot be estimated as much of the field is under the sea.

In the Wemyss district a cannel-band occurred in the Parrot Coal, which lies from 10 to 15 fathoms above the Pirnie Parrot. The seam is now worked out in those areas where it contained cannel.

MIDLOTHIAN.

Lower Limestones.—In the cutting east of the bridge over the railway at Crossgatehall (6 in. Sheet 8 N.E.), there is an exposure of a parrot-shale 8 ft. thick. It was analysed by Dr. Pollard, the results being:—Moisture, 7·46%; volatile matter, 32·89%; fixed carbonaceous matter, 28·89%; ash, 30·76% and sulphur, ·85%. This seam deserves further investigation, as owing to its low geological horizon it possibly extends over large areas. Three-quarters of a mile N.E. of the exposure, bores have shown 'parrot shale' varying from 3 ft. 5 in. to 7 ft. 1 in. in thickness, which may be taken to be the same seam.

CARBONIFEROUS LIMESTONE SERIES. EDGE COALS.

The Arniston Parrot Seam, the lowest of the Edge Coals, is a compound seam of household-coal (Jewel Seam of some collieries) and cannel. The cannel occurs in the middle, and at Arniston and Newbattle Collieries it varies between 6 and 9 in. in thickness. It is of high quality, yielding on distillation up to 68 gallons of crude oil, with 54 lbs. of ammonium sulphate.

The No. 1 Ironstone of Loanhead and Dryden March contains from 12 to 15 in. of 'wild parrot,' and No. 2 Ironstone contains from 10 to 18 in., which was tried as a gas-producer and reported to be of inferior quality.

The Stairhead Seam at Niddrie is a compound seam of steam-coal, cannel and blackband-ironstone. The cannel ranges up to 2 ft. 6 in. in thickness and on distillation yields 22 gallons of crude oil per ton.

The Great Seam at Niddrie contains a cannel-band 1 ft. 2 in. to 2 ft. 6 in. thick, which thins out both north and south of Niddrie. On distillation it gives up to 56·5 gallons of crude oil per ton.

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The No. 3 Ironstone of Loanhead contains from 5½ to 8 in. of good cannel on the west side of the field, but this passes elsewhere into 'wild parrot.'

Other bands of cannel occur in the Edge Coals Group, especially in the Loanhead and Penicuik districts, but information is lacking regarding their value as oil-producers; as they are generally described as 'wild parrots' they are probably inferior in quality to the seams already referred to.

Upper Limestone Group.—The Edmondstone or South Parrot of the Niddrie and Loanhead areas is a first-class cannel, part of a compound seam. The cannel portion varies from 5 in. to 1 ft. 3 in. in thickness. On distillation it yields up to 56·5 gallons of crude oil per ton, with 73 lbs. of sulphate of ammonia. It has, however, the disadvantage of coking in the retorts.

Slightly higher up in the sequence, and underlying the 'Extra' Limestone, a rough cannel appears locally at the junction of the Dryden and Bilston burns. The position of the South Parrot may be represented on the east side of the basin by a parrot-shale 6 to 10 in. thick, seen in the old Cowden Cleugh Quarry. A specimen analysed by Dr. Pollard showed 49·62% of volatile matter.

Coal Measures.—A band of parrot-shale 7 in. thick occurs in the middle of the Parrot Rough Coal at Whitehill and Polton. It was frequently distilled, and is stated to have yielded 40 gallons of crude oil per ton.

LINLITHGOWSHIRE.

The Jewel Coal of the Bathgate district contains a band of cannel which is very variable, being absent in parts of the field and reaching 1 ft. in thickness in others.

The Six Foot Seam of Kinneil contains cannel from 0 to 10 in. thick, said to be of good quality.

The Lower Parrot and Ironstone, at a slightly higher level, includes cannel up to 14 in. thick, but the seam is probably mostly worked out.

The Balbardie Gas Coal Seam of the Bathgate district was once well known for the high quality of its associated cannel, about 7 in. thick, which for practical purposes may now be regarded as exhausted.

Upper Limestone Group.—The Castlecary Limestone is often overlain by an oil-shale, which, near Levenseat, is 15 in. thick, and was distilled for oil in the early days of the oil-industry. It yielded 33 gallons of crude oil per ton.

Coal Measures.—The celebrated Boghead or Torbanehill Mineral, yielding 120 gallons of crude oil per ton, is now exhausted. Another coal occurring higher up in the series was worked also as an oil-producer. It yielded 29·70 gallons of oil per ton.

CENTRAL COALFIELD.

The cannels and gas-coals of the Central Coalfield are, on the whole, much thinner than those of the East of Scotland, and the better seams are now practically wrought out.

The lowest seam is the Lillie's 'Shale' and Coal, which occurs in the Lower Limestone Group of the Paisley district. The thick-

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ness of the compound seam ranges up to 2 ft. and the 'shale' portion yielded 45 gallons of crude oil per ton. It was worked from 1870 to 1886 and there is probably little reserve left.

The Lesmahagow Gas Coal is practically exhausted, and so is the Wilsontown Gas Coal. The other cannels of this group in the Central Coalfield occur only as ribs in seams of ordinary coal or blackband-ironstone. Thus the Nine-foot Seam of Coalburn and Auchlochan contains a cannel-rib about 6 in. thick, yielding from 34 to 37 gallons of crude oil per ton. The Six-foot Seam of the same district contains a cannel of about the same thickness, with a yield of 52 gallons of oil, and the Big Drum Coal has a very irregular band varying in thickness from a few inches up to 2 ft. 6 in.

The cannels associated with blackband-ironstone need not be considered here, as they are thin and irregular, and the seams are, moreover, approaching exhaustion. Blackband-ironstone is now being wrought in Scotland only on a very small scale.

In the Upper Limestone Group, the Climpy Gas Coal is exhausted, but there are probably some reserves of the Ponfeigh Gas Coal, which is a compound seam containing up to 1 ft. 8 in. of cannel. An analysis for gas-making purposes showed 53·81% of volatile matter.

The Kiltongue Musselband Shale and Ironstone has been worked at a few localities for oil, and has been tried as a possible iron-ore. It occurs over the whole of the Central Coalfield, and shows typically:—

Dark parroty blaes	1 ft. 6 ins.
Tough shale or cannel	4–9 ins.
Shale with "mussels," often irony	8 ins.
Ironstone	2 ins.
Fireclay or blaes	

The yield of oil was between 30 and 50 gallons per ton. The associated iron-ore has been proved to be of very inferior quality.

The Craw or Gas coal of the Falkirk Coalfield is a compound seam of gas-coal and ironstone. At Crosscroes the gas-coal portion is 8 in. thick. The shale above the Virtuewell Coal was also among the materials used for distillation. It has been known to reach a foot or more in thickness, though it seldom exceeded 6 in. It was rich, yielding up to 72 gallons of oil, but is now practically worked out.

The Splint Coal characteristically contains a band of gas-coal of variable thickness, oscillating between 4 in. and 1 ft. It used to be distilled, and the yield was about 32 gallons per ton. The seam is now approaching exhaustion.

One of the Douglas Coal Measure seams contains at places a cannel up to about 2 ft. 3 in. thick, which in a distillation-test has yielded 47·1 gallons of crude oil per ton.

AYRSHIRE.

Cannels for gas-making purposes have been extensively worked in this coalfield. On a smaller scale they have been mined for oil-making. There have been few recent developments, consequently a large part of the present account is based on information already published mainly in Mr. R. W. Dron's 'Coal Fields of Scotland' and among the valuable analyses of Mr. G. R. Hislop.

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Carboniferous Limestone.—At Glenbuck, near Muirkirk, the Three-foot Seam and the Nine-foot Seam contain a band of gas-coal 5 and 11 in. thick respectively, which have been worked for gas-making.

Another gas-coal, 7 in. thick, and stated to be very rich, occurs 6 fathoms above the Three-foot Seam.

At Guelt, N.E. of New Cumnock, a gas-coal, known as the Clay Gas Coal, is reported to have been 1 ft. 8 in. thick. A gas-coal, 1 to 6 in. thick, worked long ago at Dalgain Pit, ½ mile N. of Sorn, may correspond with the Clay Gas Coal.

Cannel from one of the Dailly coal seams gave 46 gallons of crude oil in a distillation-test.

At Kilbirnie the 'Wee Coal' is a gas-coal, and is now worked out. A gas-coal about 12 in. thick was also found near Barmill. The cannel-coal of Wardend Colliery, near Kilmaurs, yields from 39 to 53·7 gallons of crude oil per ton. Oil-works for its distillation were being erected when the war broke out.

Coal Measures.—At New Cumnock two cannel-seams have been known for a long time and have been extensively wrought. Various names have been applied to them: Upper and Lower Gas Coals, Lanemark Cannel, Bank Cannel, Mansfield Cannel, Pathhead Shale and South Boig Shale. Mr. R. W. Dron[1] states that an intermediate seam, not yet wrought, has been found to reach at places a thickness of 24 in.

In the North Ayrshire Coalfield, cannel was retorted at Fergushill, N.W. of Kilmarnock, from 1864 to 1878, and also at the Craigie and Hurlford Oil Works, Kilmarnock, between 1864 and 1876. Remarks attached to Mr. G. R. Hislop's analyses show that the Fergushill 'Shale' was 6 in. thick and contained 31·04% of volatile matter. The Fergushill 'Cannel' was 9 in. thick, with 37·67% of volatile matter.

The cannel raised at Auchenharvie Colliery was 7½ in. thick, with 34% of volatile matter. The Bourtreehill Cannel was 6 in. thick, with 38% of volatile matter, the Caprington Cannel was 10 in. thick, with 37·4% of volatile matter, and the Eglinton Park Cannel, 6 in. thick, contained 39·22% of volatile matter.

In the area around Kilmarnock a parrot coal, between 1 and 2 ft. thick, occurs a few fathoms above the Hurlford Main Coal; analysis shows 24% of volatile matter. Locally, at Galston, the Linnbed and the Major Seams contain cannel-ribs with 34% of volatile matter. The shale on top of the Tourha Coal has given 14% of volatile matter on analysis.

ARGYLLSHIRE.

The small Campbeltown coalfield contains a compound seam of cannel and coal, some 40 fathoms below the Index Limestone. The thickness of the cannel portion reaches up to 20 or 25 in. The top portion yields up to 36 gallons of crude oil per ton, and the bottom part 27 gallons. It has been worked to some extent in the past, but is not wrought at present. The field has not been proved sufficiently to show whether the seam preserves its character throughout, but it possibly extends over an area of two or three square miles.

[1] *Op. cit.*

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LEAD AND ZINC IN SCOTLAND.

During the past year an investigation into the lead- and zinc-resources of Scotland has been conducted by Mr. Wilson, and in the course of the work the more important mining-districts have been visited. The results tend to show that, whilst some of the districts such as Leadhills, Wanlockhead, Newton Stewart, Tyndrum and Strontian may under favourable conditions be capable of further development, most of the others are either too remote or the veins too poor and few, to warrant exploitation under present circumstances. Previously to the war Leadhills and Wanlockhead were the only working lead-mines in Scotland, but the increased price of lead and zinc, and the scarcity of tonnage, resulted in the opening-up of old mines near Newton Stewart and Tyndrum, and of a small new mine at Achanarras in Caithness.

The average yearly output for the 10 years previous to the war was about 3,550 tons of galena and about 280 tons of zinc-blende. From 1914-1918 the annual output has risen to 4,340 tons lead-ore and 1,250 tons zinc-ore, the increase being due partly to the opening up of old or new mines, but mainly to increased production from the Leadhills and Wanlockhead districts.

Leadhills and Wanlockhead.—These two adjoining districts contain by far the most productive lead-mines in Scotland. The mines have been worked spasmodically since very early times, but for 250 years have practically been in continuous operation and must have produced upwards of 500,000 tons of lead-ore.

The rocks of the area are of Ordovician age, and the general succession is as follows:—

Caradoc	...	Lowther Group	... 1,000 ft.
Llandeilo	...	Lower Hartfell Shales Glenkiln Shales . Radiolarian Cherts ...	... 40–50 ft. ... 60–70 ft.
Arenig ...	...	Volcanic and Intrusive rocks (thickness unknown)	

The metalliferous portions of the veins are usually associated with the Lowther Group which, consisting mainly of hard, calcareous shales and greywackes, give rise on fracture to open fissures suitable for infilling by ore-bearing solutions. The productive veins are arranged along a N.E. and S.W. axis and occur within a lens-shaped area about 14 miles long by 4 or 5 miles in width.

The veins can be divided into two intersecting main sets. The trend of one set varies about 45° on either side of north and that of the other from W.N.W. to N.W. Little evidence exists as to the relative ages of the two sets, but such as there is points to the W.N.W. set being the older.

About 70 veins are known, and lead-ore has at some time or other been produced from practically all of them. At present, however, only four are being worked—namely, the New Glencrieff and its west branch, 'The West Grove,' at Wanlockhead, and Brow and Brown's Veins at Leadhills. The workings at both localities are extensive and have reached a depth of about 240 fms. The veins, whose walls are well defined, vary from mere strings to 16 or 18 ft. in width, and are usually filled with a breccia of greywacke-fragments, cemented by a calcite-matrix often containing interspersed galena. The whole is also cut by

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numerous vertical strings of galena varying from ½ in. to 3 or 4 ft. in thickness, and in exceptional cases from 12-14 ft. of solid galena has been seen. At the present time the average values of the slopes are about 10 cwt. to 1 ton of ore per fathom at Wanlockhead, and 1 to 2 tons per fathom at Leadhills.

The primary minerals of the veins are galena, jamesonite, zinc-blende, pyrites and chalcopyrite. Of these galena only is worked at Leadhills, but at Wanlockhead blende also has been extracted since 1870. About the middle of the 18th century one or two veins were worked for copper-ores.

The common gangue-minerals are calcite, dolomite, quartz and barytes, but none occurs in sufficient quantity to pay for extraction. A cavity recently opened at the 200 fm. level in the West Branch of the New Glencrieff Vein yielded the first authentic specimen of Scottish witherite. The mineral occurred in beautiful radiating masses which are evidently secondary after barytes.

The veins are exceedingly rich in secondary minerals, due to oxidation of the primary sulphide ores. Several of the rarer species, such as leadhillite, caledonite and lanarkite, were first recorded from the district.

Newton Stewart.—A large number of mineral veins carrying lead-, zinc-, and copper-ores occurs around the Cairnsmore Granite mass. Blackcraig Vein was accidentally discovered in 1763 during the making of the Military Road, and, soon after, the mine was opened up and the ore shipped to Chester for smelting. During the recent visit to the localities, it was found that at Wood of Cree, now being opened up and worked, an interesting view of the vein can be obtained. The walls are ill defined, and the country-rock for a few yards on either side is impregnated and strung with thin veinlets of ore. In addition there occurs near the centre of the vein a definite brecciated zone containing strings of galena and blende ranging up to 4 in. in thickness. Many of the veins of the district are of this composite type, and at Blackcraig the 'bearing ground,' as the impregnated country-rock is called, attains in places a width of about 20 yards.

Tyndrum.—The veins of this district were accidentally discovered in 1741 by Sir Robert Clifton who at that time held the mining lease of the Breadalbane property. He opened up the mine and raised 1,697 tons of lead-ore between 1741 and 1745. From that time to 1768 the mine passed through various hands, and in all about 3,318 tons of ore were raised. In 1768 the Scots Mining Co. obtained a lease, erected a smelting-mill about 1 mile east of the mine, and between 1768 and 1790 produced 1,678 tons of lead from 3,683 tons of ore. After 1790 work was only carried on intermittently till 1858 when the late Marquis of Breadalbane took the mines into his own hands. From 50 to 100 tons of ore were raised annually till his death in 1862, when work ceased. In 1917 the mines were taken over by the Tyndrum Mines, Ltd., and are now being opened up.

This district is situated in an area of metamorphic rocks consisting mainly of mica-schists, quartzites and quartzose-flags with occasional interbedded schistose bands. A large N.E. fault, throwing down to the S.E., crosses the area, and, as will be seen from

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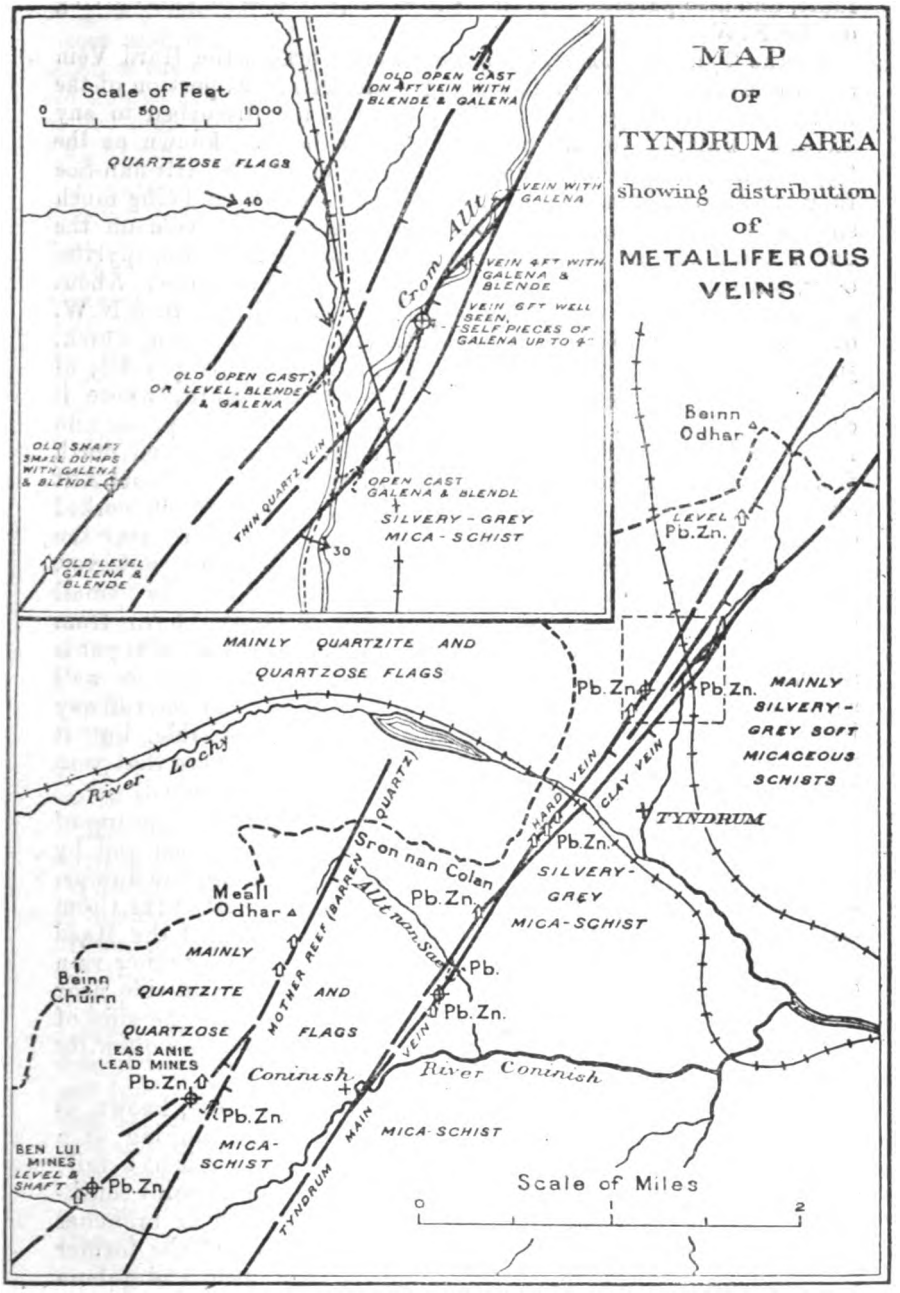
FIG. 1.



OLD SHAFT LEVEL OPEN CAST

VEIN CERTAIN, a crossmark on hanging wall. VEIN UNCERTAIN

Pb. LEAD ORE Zn. ZINC ORE

The inset map represents the small area indicated to the north of Tyndrum on a larger scale.

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the map, Fig 1, the metalliferous veins are situated along this fault, and also parallel to it in the area of quartzose rocks occurring on the N.W.

At the Tyndrum Mines two veins were worked, the Hard Vein and the Clay Vein, the latter being a metalliferous portion of the main fault. The ground between them is not disturbed to any extent. Farther to the S.W. the veins become known as the 'Tyndrum Main Vein,' and where they cross the Allt-nan-Sae they are about 100 yards apart, the rock between them being much shattered and strung with thin quartz veins. The vein on the north boundary of this shatter-zone contains a little iron-pyrites only, but that to the south contains also galena and blende. About a quarter of a mile farther south an old level, driven in a N.W. direction, appears to have cut the southern limb of the vein, which, judged by the material in the dump, contained a fair quantity of complex lead- and zinc-ores. Farther south again, where it crosses the Coninish River the vein has recently been opened and found to contain a fair quantity of galena. When traced north from Tyndrum the veins are not seen till they cross the Crom Allt about 1 mile from Tyndrum. Here the Clay Vein has been worked opencast a short distance on the N.E. side of the burn, near the road. About a quarter of a mile farther up the burn, however, the fault (Clay Vein) can be seen to contain no ore. Two small offshoots, both of which are metalliferous, cross the burn from the west side, and are cut off against the fault. About 200 yards southwards they apparently join, and the conjoint vein is well seen crossing the burn about 100 yards upstream from the railway bridge. The southwards extension is nowhere visible, but it probably joins with the Clay Vein near the point where that vein is metalliferous, at the small open-cast already mentioned.

The Hard Vein can be traced from Tyndrum to near the top of Beinn Odhar, where it was at one time worked opencast and by level. A little galena and blende can still be found on the dumps. An old shaft and a level about a quarter of a mile west of the Crom Allt railway-bridge, are also probably on the course of the Hard Vein. About half way between the two main veins, another vein can be traced by trials, and an old level from the road-side near the railway-bridge to a point about $\frac{1}{4}$ mile away up the side of Beinn Odhar. It is about 4 ft. wide and contains a fair quantity of blende and galena.

Ben Lui and Coninish Mines.—A barren quartz-reef, known as the Mother Reef, is shown on the map (Fig. 1), running in a N.E. direction from the Eas Anie to Meall Odhar. About $\frac{1}{3}$ mile N.E. of Eas Anie it appears to branch, and from this point southwards becomes metalliferous. The westerly branch or branches have been worked at Eas Anie and at Ben Lui. At the former place the levels on the more westerly branch are open, and galena and blende associated with barytes can be seen. At Ben Lui the same minerals occur on the dumps at the mouth of the level.

The easterly branch, which keeps the same trend as the Mother Reef, is visible at a trial on the hillside about a quarter of a mile S.E. from Eas Anie and there shows a fair quantity of blende and galena.

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The veins contain a complex ore scattered through a quartz-gangue. The galena and blende are usually, however, in small pieces and intimately mixed, so that it has been impossible to separate them, but with improved plant this may be possible. The old dumps at the Tyndrum Mines are estimated to contain about 40,000 tons of material yielding approximately 9·5% of lead and 6·5% of zinc.

Strontian.—These mines and those of Lurga in Morvern are believed to have been discovered by Sir Alexander Murray, of Stanhope, in the early part of the 18th century. He was the proprietor of Strontian and appears to have leased the mines to the Duke of Norfolk, who afterwards made them over to the York Buildings Co. The Lurga Mines were leased from the proprietor, the Duke of Argyll, and in a statement made by Duncan Forbes, of Culloden, to the Duke of Argyll in 1737 we find that the rent paid was £41 17s. 7½d. In 1733 an interesting map and account of the area was published under the title, 'A Plan of Loch Sunart.'

The Strontian Mines were worked continuously till 1815, but since that time the workings have been intermittent and on no great scale. In 1809 the output seems to have been about 400 tons of lead per annum, but it gradually fell away, and when work ceased in 1871 it was only 9 tons.

The country-rock varies from hard mica-schist, with banded quartzites in the west near Coire-an-t-suidhe, to augen-gneiss at Fee Donald in the east.

The veins, several of which have been worked, all have a trend of about 5° N. of W., and except at Coire-an-t-suidhe are associated in each case with a highly-decomposed basalt dyke.

The primary ores are galena, jamesonite and zinc blende with a little pyrites. Galena has been worked extensively at Strontian (Whitesmith and Bellsgrove Mines); at Coire-an-t-suidhe 30 tons of blende also were extracted in 1871. The gangue consists mainly of barytes and calcite, occasionally with small quantities of strontium-minerals such as strontianite and celestine.

The Lurga vein is situated in Glen Dubh on the estate of Laudale and about 3 miles south of Laudale House, on the south side of Loch Sunart. It is of the same type as the Strontian veins and like them is accompanied by a decomposed basalt dyke. The ores are mainly galena and blende associated with white barytes and quartz, and at one part the vein shows about 4 ft. of fairly clean barytes.

The Strontian veins have been worked to a depth of over 100 fms., but the workings are now full of water to adit-level.

The Coire-an-t-suidhe vein, which is visible at several places, contains a fair quantity of galena, perhaps 10 cwt. per fathom, together with blende up to 1 ft. or 18 in. thick still remaining on the footwall of some of the opencast workings. The higher workings are full of water, from which it may be inferred that the vein is water-tight, and that the low level cannot have been driven far into the hill.

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BAUXITIC FIRECLAY IN SCOTLAND.

Much interest having been aroused in the Ayrshire Bauxitic Clay as a promising refractory material, this opportunity is taken of giving a brief account of its character and origin, and a history of its discovery.

The clay is of Millstone Grit age and the general sequence of that series in North Ayrshire is as follows:—

Saltcoats bauxitic clay	6–24 ft.
A series of lava-flows with interbedded foul coal, fireclays and ganisters	6–40 fms.
Monkcastle clay	10–20 ft.
Sandstone	20 ft.

It will be seen that the sequence consists mainly of igneous rocks with fireclay-deposits both above and below, but whereas the lower fireclay seam is simply a high-grade clay of the ordinary type, the upper seam has properties such as hardness, conchoidal fracture, oolitic structure, and high percentage of alumina, which are not found in ordinary fireclays, but more nearly resemble those of bauxite. On the other hand, bauxites contain a large amount of free alumina soluble in hydrochloric acid; while in this deposit the bulk of the alumina is combined with silica in the form of some mineral after the nature of kaolin, and the excess alumina is not to any great extent soluble in acid. The occurrence of the deposit at the top of a series of basalt lava-flows, and its intimate association with beds rich in iron and resembling laterites, suggest that the origin was in many respects similar to that of bauxite, but whereas that material is an exceedingly porous rock the Saltcoats bauxitic clay is compact, and only slightly porous. This difference suggests that the rock, though originally deposited as a normal bauxite, has undergone silicification, but the possibility of its having been originally deposited in its present form is not excluded.

Mr. John Smith, of Dalry, was probably the first to recognise the lateritic origin of the ironstone-seams that occur at the top of the Millstone Grit Series in Ayrshire, and an attempt was made to work them for iron-ore at an exposure on the Lugton Water, near Sevenacres Mill. It was not, however, till the recent revision of the area by the Geological Survey that the bauxitic character of some of the beds attracted attention. Two samples were analysed, and of these one, collected by Mr. E. M. Anderson from the outcrop on Saltcoats shore, yielded 47·7% of alumina. This result was communicated to Mr. W. Douglas, of Kilwinning, who was then working the Monkcastle Clay. He submitted further samples to Dr. Mellor, of Stoke-on-Trent, who reported a refractory quality of over Seger Cone 35.

At that time the late Dr. C. T. Clough was engaged in mapping the Kilmarnock district, where also both of the fireclay horizons are represented. He had samples collected from above and below the Millstone Grit lavas and provided the funds for the conducting of a series of refractory, shrinkage and porosity tests by Dr. Mellor. The results were disappointing, for from neither horizon was the clay nearly so refractory as that of the same bed in the west.

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The occurrence of this bauxitic clay was made known to a number of people who were inquiring as to the sources of refractory and other materials, but the first to take leases of the ground and to work the clay were Messrs. Adamsez, Ltd., of Scotswood-on-Tyne. The results obtained by its use were so satisfactory that other firms became interested, and several other areas were taken up. Among the special properties which attracted attention, mention may be made of its high resistance to heat and its suitability for those portions of furnaces which are exposed to the highest temperatures, such as the gas-ports of glass-furnaces. It has also proved specially useful for electric steel-furnaces. Probably on account of its hardness and its non-plastic nature, alone it is not easily made into bricks and other shapes, but means have been found of overcoming this difficulty, and many forms of fireclay goods made from it are now on the market. It seems likely that this clay, and other similar clays, if they can be found, will fill a definite place in the British refractories industry.

The Millstone Grit Lava Series has been recognised over a great part of North Ayrshire, and in the Island of Arran. The main outcrop has been traced from Saltcoats shore to the Fenwick Water, near Kilmarnock, and north of it a few outliers have been located to the north of the Dusk Water fault, as, for instance, the strip running from the Glenburn to Monkcastle and that from Blair to near Giffen House. Southwards from the main outcrop the presence of the bauxitic clay is not yet fully proved. Since the lavas are again found outcropping to the south of the Galston-Dundonald fault, and the bauxitic clay has been recognised in some of the bores along the northern edge of the Mauchline basin, it seems that the deposit may underlie the whole of the North Ayrshire Coal Measures, though the possibility of its having been eroded locally before the deposition of the Coal Measures must not be overlooked. Its extension into the South Ayrshire Coalfield has not been proved. The presence, however, of detrital deposits of the same nature at Sanquhar and Stranraer warrant the hope that it may exist in the Ayr, Dalmellington and Cumnock districts.

The presence of the seam in Arran proves its wide westward extent and suggests its probable occurrence under the Firth of Clyde, where Coal Measure seams have already been worked from Stevenston and Saltcoats. Several of these workings are, however, now full of water.

The bauxitic clay is usually of a pale-grey to buff colour, but reddish, green, mottled, and even black varieties are common. The hardness varies from that of a hard limestone to a limey blaes or marl. The fracture is conchoidal and innumerable joint-planes cause the material to weather down in a debris of small cubic or rectangular blocks.

The rock is fine, even-grained in texture and often contains numerous rootlets; in other parts the texture is distinctly oolitic and these oolitic varieties are the richest in alumina. In both of these types the original structure has almost entirely disappeared, but in some beds it can still be made out. In many cases the parent-rock has been a volcanic ash and in others a lava, for

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it shows the remains of what appear to have been amygdules. The seam, though remarkably persistent, varies in thickness, character and chemical composition. At Saltcoats the section exposed shows about 11 ft., composed of the following beds:—

	Ft.	In.
Fine-grained grey clay with rootlets	2	6
Dirty coal	2	–
Black clay	2	3
Hard grey clay with angular fragments (volcanic ash) ...	1	6
Black clay	–	4
Fine-grained grey clay with rootlets	1	4
Hard grey oolitic clay	1	3

At the exposure on the Lugton Water, near Sevenacres, the section is as follows:—

	Ft.	In.
Pale buff-coloured fine-grained homogeneous clay with rootlets	3	–
Pale-grey clay weathering spheroidally	3	–

The exposure in the Annick Water gives the following section:—

	Ft.	In.
Hard white clay...	2	6
Ironstone rib (decomposed basalt)	2	6
Hard white clay...	2	3
Black speckled clay passing down into altered volcanic ash	1	2
Irony rib	–	2
Hard white clay passing down gradually into decomposed lava	2	6

The chemical composition of the deposit is not uniform and the constituents vary as follows:—Al_2O_3, 26-50%; SiO_2, 28-50%; Fe_2O_3, less than 1-8%, TiO_2, 2-14%, combined water 7·5-15%. In composition, therefore, the deposit varies from a normal fireclay to a siliceous bauxite, but mineralogically it differs from a bauxite in that the alumina is not in a free state, soluble in hydrochloric acid. In many of the samples examined some, if not all, of the titanium is in the state of rutile (TiO_2), which is an exceedingly stable substance but considerably reduces the refractory quality of the clay when present in a proportion of more than 5%. The iron may be present either as small specks of the carbonate (sphaerosiderite) or as pyrites. The refractory quality of the clay is also exceedingly variable, ranging from Seger Cone 38 for the best oolitic material to Cone 29 for the inferior types. From the evidence as yet to hand, the lenticular pockets of high-grade material seem to be better developed at the Saltcoats end of the field, but there appears to be no reason why they should be thus restricted.

REVISION OF PARTS OF BANFFSHIRE AND ABERDEENSHIRE.

The districts around Portsoy, Banff, Boyndie and Cornhill in Sheet 96, and around Glenbarry, Rothiemay, Huntly, Kennethmont, Insch, Rayne and Daviot in Sheet 86 have been mapped by Mr. Read. The area was originally mapped mostly on the 1″ scale by Dr. Horne in 1881-4; the portion revised, which occupies some 200 square miles, is illustrated in Fig. 2.

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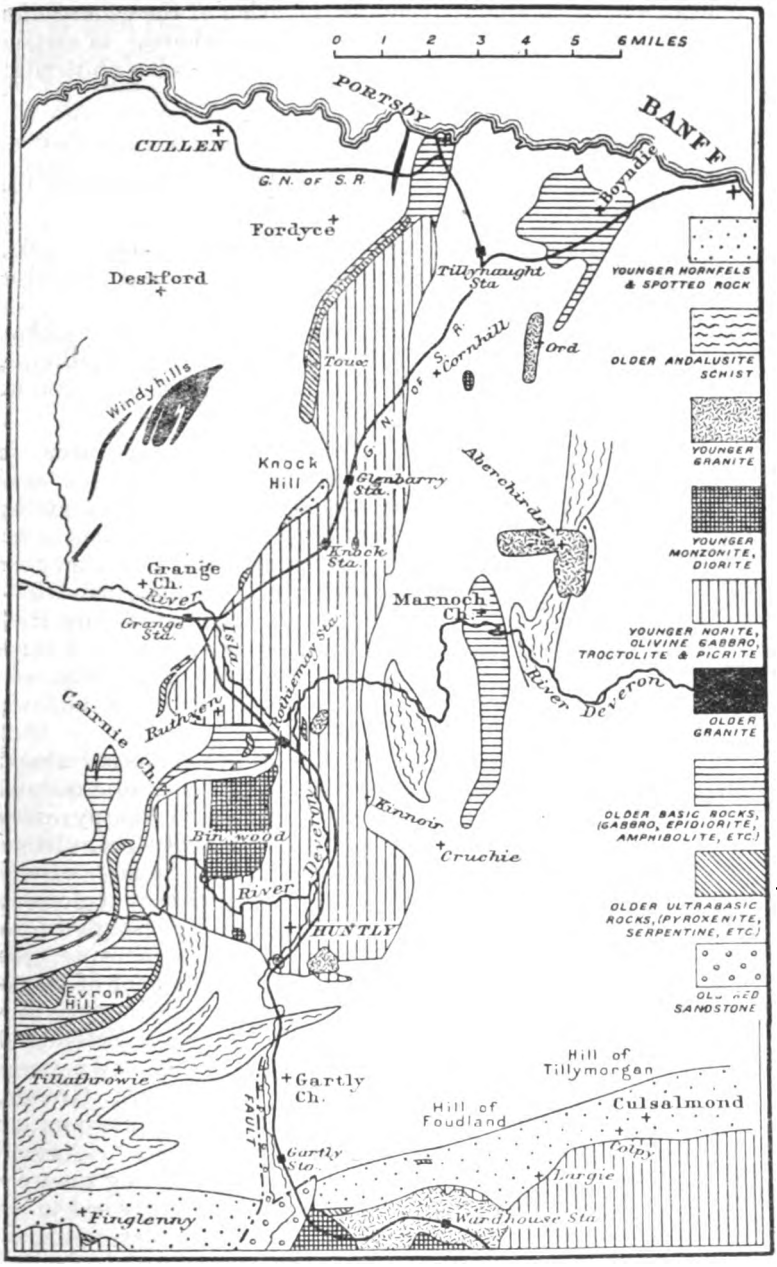

Fig. 2.—Sketch Map showing distribution of Igneous Rocks, Contact-rocks and Older Andalusite Schist in Strathbogie and Lower Banffshire.

The igneous rocks are separable into two classes: an Older Series—intruded largely prior to the movements which caused the present disposition and foliation of the schistose rocks, and a Younger Series—intruded after those movements. The thermally

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metamorphosed rocks produced by the intrusion of the Older Series have been foliated by the later movements, whereas in certain places contact metamorphism by the Younger Series has obliterated the older foliation of the country rocks.

THE OLDER IGNEOUS ROCKS.

The Older Igneous Rocks are capable of division into the following classes:—

(1) *Ultrabasic.*—Olivine rocks, olivine-pyroxene rocks, pyroxene rocks, with derived serpentinous and tremolitic rocks.

(2) *Basic.*—Labradorite rock, gabbro, enstatite gabbro, diorite, with derived hornblende gabbro, epidiorite, amphibolite, hornblende schist and hornblende granulite.

(3) *Acid.*—Granites with derived augen gneisses.

1. *Ultrabasic Older Igneous Rocks.*—These rocks occur in general intimately associated with the basic older igneous rocks and are probably the oldest of this series, since they are cut by thin epidiorite dykes. They form long sill-like masses, most of which, but not all, occur about one horizon east of a limestone which is east of the quartzite forming the ridge of Durn Hill—Knock Hill—the Balloch. Smaller lenses occur at White Hill, Mortlach and Avochie Castle, around Rothiemay Station. A large mass shows at Hill of Milleath, 4 miles west of Huntly, and ultrabasic older igneous rocks are well developed on both flanks of Evron Hill and Brown Hill of Glass.

The predominant type of this division is a rock composed almost entirely of augite, with subordinate and rather sporadic olivine. As seen at White Hill, in a rock crushed when solid, the pyroxene occurs as large angular plates in a matrix of finely granulitised augite of a character similar to that of the plates. In more altered specimens, the granulitised pyroxene is replaced by colourless tremolite blades and greenish serpentine; the final stage in the alteration is exemplified by a rock composed of serpentine, iron oxides, and large blades of tremolite. The development of tremolite and the degree of crushing of the rock are intimately connected. Similar rocks are seen at Hill of Milleath, Hillside of Glass and Craigs of Succoth. Among other varieties may be mentioned a pyroxene serpentine occurring at Ballochburn, Grange, a slaty foliated serpentine at Drumnagaroch, Grange, and an olivine hypersthene hornblende rock at Meikle Toux. Around Portsoy, several crops of ultrabasic type occur, providing the well-known 'Portsoy Marble.' The larger and more westerly bed to the west of the town is an olivine serpentine, the smaller and more easterly bed shows tremolite, pyroxene and calcite and is derived from a pyroxene rock. The serpentine of the Burn of Durn below Aird Bridge, Portsoy, contains abundant bastite and is associated with enstatite gabbro. Several small bosses of serpentine occur at East Head, east of Portsoy.

In conclusion, therefore, it may be stated that the original rock of the majority of the ultrabasic older igneous rocks of this area was one composed largely of pyroxene, in most cases augite, more rarely a rhombic pyroxene; olivine occurs in subordinate amount,

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although it may be locally abundant. The whole series is much altered with the production of serpentine and tremolite, the formation of which has been aided by the development of crushing and foliation.

2. *Basic Older Igneous Rocks.*—The basic older igneous rocks are well seen at Portsoy, around Boyndie, south of Ruthven and on both sides of the Deveron west of Huntly. A detached sill-like mass runs north and south from Marnoch Church nearly to Cruchie.

This series of rocks is much altered both structurally and mineralogically, but it has been possible to delineate the sequence of the alteration by the examination of a large number of thin sections. The least altered type is seen at Portsoy. This rock, a true *gabbro*, consists of labradorite and large ophitic plates of augite, marginally altered to brownish-green hornblende. Biotite, iron oxides and apatite complete the rock. Locally enstatite may be present in addition to the monoclinic pyroxene. More acid bands occur in these gabbros characterised by the presence of quartz and a medium plagioclase. The second stage in the alteration is marked by the complete disappearance of the pyroxene, whose place is now taken by aggregated prisms or compact plates of secondary hornblende. At the same time the turbid original plagioclases show within them a few clear grains of secondary felspar. This rock, which is not structurally altered, may be called an *epidiorite*. The third stage in the alteration is characterised by the growth of innumerable needles and prisms of hornblende at the edges of the secondary hornblende plates. The felspar becomes filled with these wandering prisms and, at the same time, it is replaced by a mosaic of grains of clear felspar usually of more acid composition. The iron oxide has mostly gone over into leucoxene; epidote occasionally occurs. This is the *amphibolite* type, in which hornblende is largely in excess of felspar, but it should be noted that no schistose structures have been developed.

With the development of schistose structures a second series may be produced. The first type is a *gabbro schist*, in which hornblende and labradorite are arranged in parallel bands. The amphibole is secondary from pyroxene, but most of the plagioclase is original, although granulitisation is sometimes well developed. A further stage produces a true *hornblende schist* with hornblende in excess of the felspar, well-marked schistose structure and complete granulitisation and recrystallisation of the felspar; the final stage produces a *hornblende granulite* in which felspar and hornblende (with some biotite) are associated in rounded grains. All these types may be found at Portsoy.

The complete failure of ferromagnesian minerals (perhaps related to the complete failure of felspar in the neighbouring pyroxene-rock) has produced at Portsoy a rock composed wholly of labradorite felspar, approximating in character to the anorthosite of Canada.

To summarise the investigations on the basic older igneous rocks it can be said that the original rock was a pyroxene-labradorite rock or gabbro. By the amphibolisation of the pyroxene is pro-

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duced first the epidiorite type; by the growth of secondary hornblende in the felspar together with concomitant production of secondary felspar in granules, an amphibolite is formed. Movement has produced the types of gabbro schist, hornblende schist and hornblende granulite.

3. *Acid Older Igneous Rocks.*—Older igneous rocks of acid composition occur at two localities. One mile west of Portsoy an augen gneiss forms a narrow lens in the schists. In this rock, large eyes of microcline, orthoclase and subordinate oligoclase are set in a cataclastic ground mass of granular quartz and felspar with shreds of primary biotite; much secondary muscovite occurs along shear planes.

The second area of foliated granite is around Windyhills. The rock shows large phacoids of pinkish felspar separated by flaser of greenish and silvery micas. This foliated variety passes into a coarse-grained porphyritic non-foliated granite.

THE YOUNGER IGNEOUS ROCKS.

The younger igneous rocks are remarkable for their variety, extent and contact effects. They form a broad belt stretching from Huntly northwards to within two miles of Portsoy; this may be called the *Huntly Mass.* The northern part of a second belt is found on the southern edge of Sheet 86 and may be called the *Insch Mass.* Isolated granite bosses occur at Aberchirder, Ord and Longmanhill (4 miles E.S.E. of Banff).

(*a*) *Huntly Mass.*—The following scheme shows the classification of the Younger Igneous Rocks of the Huntly Mass, and their relative ages, beginning with the oldest:—

1. *Picrite-Norite Set.*—Picrite, Olivine Gabbro, Troctolite, Norite.
2. *Diorite.* (Gibstone).
3. *Monzonite and Diorite.*
4. *Granite.*
5. *Tourmaline Pegmatites.*

These rocks are best exposed in the district around Huntly and have been described for that area by W. R. Watt,[1] on whose work the following description, in so far as it applies to the Huntly district, is of necessity largely founded.

1. *Picrite-Norite Set.*—This composite intrusion is best displayed to the west of Huntly. Its members are picrite (olivine, augite, little felspar), olivine gabbro (olivine, augite, plagioclase), troctolite (olivine, labradorite), and norite (hypersthene, augite, labradorite). These members occur from west to east in the order given, the picrite forming a rather narrow border to the mass, followed eastwards by a small development of olivine gabbro and this again by more widespread troctolite. All these types occur in the western parts of the Bin Wood and Dunbennan Hill. The norite is the most widely developed forming the main parts of the intrusion, and related types extend northwards from Huntly nearly to Portsoy. Troctolite and picrite occur in the railway cutting

[1] W. R. Watt, "The Geology of the Country around Huntly (Aberdeenshire). *Quart. Journ. Geol. Soc.*, 1914, pp. 266–293.

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at Rothiemay Station, and troctolite also occurs west of the norite between Grange and Knock Stations. It seems probable that the Picrite-Norite Set were intruded into one another whilst they were all fluid after a period of differentiation in a lower magma.

2. *Diorite.* (Gibstone).—A small knoll of foliated diorite (quartz, biotite, augite, andesine) occurs near Gibstone (1½ miles north-west of Huntly) in an area of unfoliated norite. It is intermediate in composition between the norite and the later monzonite, and its foliated character may be explained by its being still hot and soft at the time of the movements which caused the monzonite to present a markedly intrusive character towards the norite. An allied type, but unfoliated, occurs at Craigwillie, 1 mile west of Huntly.

3. *Monzonite and Diorite.*—Intrusive into the already solid picrite-norite set are the Bin Wood monzonite and associated Cormalet mica diorite. These rocks were called by W. R. Watt the *Central Intrusion.* The monzonite consists of orthoclase, plagioclase, augite, biotite, quartz and widespread garnet. Its contact effects on the neighbouring norite will be described later.

4. *Granite.*—Granite (quartz, orthoclase, microcline, plagioclase, biotite and muscovite) occurs in several small masses, but is quite subordinate in amount to the more basic igneous rocks of this period. At Carvichen (1 mile S.E. of Huntly) the granite is marginal to the norite; at Rothiemay (Avochie) and Ternemny (Knock Stat.) the granite masses are surrounded by norite. The granites of Aberchirder, Ord and Longmanhill occur, unassociated with more basic members, in the metamorphic rocks.

5. *Pegmatites.*—Numerous pegmatites with tourmaline penetrate the norite and the neighbouring schists.

(*b*) *Insch Mass.*—The microscopic investigation of the rocks of this Mass has not yet been carried far enough to permit of a detailed description.

The northern part of the Insch Mass occurs along the southern margin of Sheet 86. In the parish of Rhynie, south of Finglenny, a beautiful olivine norite occurs, composed of labradorite, olivine, hypersthene, biotite, augite and magnetite. The sinuosities of the crop of this rock have permitted some thin sill-like masses of basic and ultra-basic rock, referable to the Older Igneous Series, to peer out in detached areas.

In the Kennethmont and Wardhouse districts, Younger Igneous Rocks of various types are developed, as shown on the sketch map. Some of the rock is similar to that just described. Other varieties are more acid and approach diorite. The pink coarse-grained rock occurring around Wardhouse is found to consist of microcline, oligoclase, biotite, hornblende and a little quartz. The noritic type extends, so far as can be estimated from hand specimens, through the parishes of Insch, Culsalmond, Rayne and Daviot.

MODIFICATION OF YOUNGER IGNEOUS ROCKS BY INCORPORATION OF SEDIMENT.

Incorporation of sediment by the Younger Igneous rocks was postulated by W. R. Watt to explain the occurrence of cordierite-

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norites at Wells of Cuternach, 3¼ miles W.N.W. of Huntly. During the course of the present survey, incorporation of sediment with the consequent production of abnormal rock types has been found to be extremely widespread. Marginal exposures of the norite show the rock crowded with partially digested fragments of the neighbouring schists, mostly phyllites. This is not confined only to the norite nor only to the margin, but interior exposures of both norite and monzonite show similar phenomena. By this solution of these sedimentary inclusions a new magma of abnormal character has been produced, a salient feature of which is the occurrence of cordierite, pleonaste, sillimanite, and garnet, accompanied by rearrangements of the original constituents of the igneous rocks. Such contaminations of the Younger Igneous Rocks by sediments are manifest in W. R. Watt's original locality—*i.e.*, Wells of Cuternach, and also near Ward (1 mile W.S.W. of Huntly), in the Deveron below Huntly Castle, in the Bin Wood, in Battlehill Quarry (Huntly), at the Hill of Kinnoir, near Rivestone (1½ miles east of Rothiemay Station), around Ruthven, on both sides of the Deveron at Rothiemay village, east of Wether Hill (1 mile S.E. of Glenbarry Station) and in Glen Barry. The effect of incorporation of sediment is always to produce an abnormal rock type.

CONTACT EFFECTS OF IGNEOUS ROCK ON IGNEOUS ROCK.

As described by W. R. Watt, cordierite norites have been produced from the ordinary norite at its contact with the later monzonite of the Bin Wood. These contact rocks are characterised by the presence of cordierite, spinel, sillimanite and, very rarely, corundum. The hypersthene of the norite is partially replaced by magnetite, garnet and biotite.

Acid pegmatites were credited by W. R. Watt with the production of similar effects, but, though this may be true for certain localities, it is probably not the case at Battlehill Quarry, Huntly. The usual and widespread alteration produced in the norite by pegmatites is the development of a 'dioritic' type, characterised by hornblende, biotite, labradorite, and more acid felspars. This rock is very like some of the epidiorite-amphibolites of the Older Igneous Series. At Keillenknowes (Ladysmith), 2 miles S.E. of Rothiemay Station, thin pegmatites in the norite have produced a remarkable rock composed of large plates of brown hornblende and biotite poikilitically enclosing small andesine grains.

The Older Igneous Rocks of gabbro facies have been contact altered by the Younger Igneous Rocks at Rothiemay and to the south of Finglenny, Rhynie, with the production of a garnet felspar hornblende pyroxene granulite resembling some of the Saxon granulites.

THE OLDER ANDALUSITE SCHISTS.

The distribution of the older andalusite schist is shown on the sketch map. In the main, this rock is a silvery phyllite with very thin lamination, studded with resistant knots and crystals of andalusite. Staurolite and cordierite also occur. Often the rock is more massive, but can everywhere be distinguished from the

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younger contact altered rocks. Its origin may be explained either by regional metamorphism, or by contact alteration produced by the Older Igneous Rocks. The examination of the coast section between Banff and Portsoy seems to indicate that it is of contact origin, but until the relations of similar rocks in the eastern part of Sheet 86 have been investigated it would be premature to dogmatise as to its origin. In places, however, as at Portsoy, andalusite-staurolite schists have been unquestionably produced by the Older Igneous Rocks. What may be stated with certainty is that the older andalusite schist existed as such before the foliation and before the intrusion of the Younger Igneous Rocks.

THE YOUNGER CONTACT ROCKS.

Along the border of the Insch Mass a belt from one to two miles wide of contact-altered rocks is found. The unaltered rock is a bluish slate with an excellent cleavage, formerly worked for roofing-slate west of Gartly Station and all along the slate ridge which runs from Gartly Station eastwards by Foudland Hill to the Hill of Tillymorgan. Passing southwards off the unaltered slates and towards the Younger Igneous Rock of the Insch Mass, the first evidences of contact action encountered are the development of small rod-like markings in the slate; the cleavage is still excellent. Proceeding still farther towards the Younger Igneous Rock, the cleavage in the sediments becomes totally destroyed and a light bluish massive rock with well developed dark circular spots is formed. These spots are of various origins, being due to the heaping together of dust-like iron oxides, to the development of platy micas and to the incipient crystallisation of andalusite and cordierite. Near the Younger Igneous Rocks a true hornfels is produced, giving a massive, very fined grained, dark rock, which in slice is seen to consist of cordierite, andalusite, sillimanite, micas and quartz, with typical hornfels appearance. The norite south of Finglenny seems to have metamorphosed the older andalusite schists on Cloichdubh Hill, and, by adding its effect to the older metamorphism, has produced a coarse rock with large biotites, muscovites, and cordierite together with water-clear pleochroic crystals of andalusite.

The Aberchirder and Longmanhill granites have produced spotting in the slates into which they were intruded.

The absence of any definite aureole around the Huntly Mass is probably due to the fact that this mass is intruded, especially in its northern part, into a series of sediments which had already been altered either regionally or by the intrusion of the Older Igneous Rocks. Nevertheless, near the margin of the Huntly Mass (as shown by W. R. Watt for the Huntly district) contact rocks are abundant. This hornfels shows much garnet, cordierite, sillimanite and biotite, and occurs at numerous localities both in the Huntly district and to the north. Specially beautiful examples may be found in the partially digested sedimentary lumps abounding in the monzonite and norite, and also at Cumrie (1 mile S.W. of Rothiemay Station) and at Loangarry (2½ miles E. of Huntly). North of the Huntly district similar types are met with around Rothiemay village, and an excellent garnetiferous hornfels occurs N.W. of Knock Station.

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III.—PETROGRAPHICAL WORK.

The work carried out in the Petrographical Department during the past year has been mainly the furnishing of reports on matters of economic and scientific importance to the Admiralty and other Government departments. Dr. Thomas, as technical adviser to the Admiralty in the selection of certain materials for the Anti-Submarine Division, has supervised and carried out the testing of the selected material. A mineral from a captured German cargo has been identified. Reports have also been furnished on the resources of zirconia, and on potash- and soda-bearing rocks in the North Wales District.

Dr. Thomas has investigated and determined the mode of construction of certain German-made Nicol prisms and has shown that effective prisms can be constructed with considerable economy in Iceland spar by adopting that mode. He has also carried out experiments with good results on the construction of combination glass- and spar-prisms, in the manufacture of which a still greater economy in Iceland spar may be effected.

Typical specimens of iron-ore from the Forest of Dean examined for Professor Sibly proved to consist mainly of the mineral goethite.

The special report on British Refractory Materials (Silica rocks and Dolomites) has been proceeded with.

IV.—CHEMICAL WORK.

For the 'Special Report' on British refractory materials 44 dolomites, obtained from quarries in various parts of the country where the material is worked, have been analysed.

The tabulation of the results of the analyses of silica-rocks, mentioned in the Summary of Progress for 1917, has been proceeded with.

The percentages of soda and potash in a fresh average sample of granite from Corrennie, Aberdeenshire, have been determined. A complete analysis of the rock is desired, and the results will be given later.

A waste-product from a colliery was tested to ascertain if it could be put to any commercial use.

A mineral, taken from a captured German cargo was analysed and a report upon it was drawn up in collaboration with Dr. Thomas.

V.—PALÆONTOLOGICAL WORK.

England and Wales.

Collections of fossils obtained by Mr. Pringle from boreholes at Kimmeridge, Corton and Donnington-on-Bain have thrown further light on the zonal palæontology of the Kimmeridge Clay.

Numerous additional fossils have been arranged by Mr. Allen in the Museum-cases, including a series of types and other examples of graptolite-species illustrating papers by Harkness, Moore, Murchison, Nicol and other authors. Many of these specimens were transferred from the collection presented by the Geological Society. Another addition is a series of casts of important

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specimens from the Box Stones of Suffolk, made and presented by Mr. Alfred Bell. Thin sections of *Bennettites maximus* Carr., from the Lower Greensand of the Isle of Wight, have been cut from the type-specimen diagnosed by W. Carruthers in 1870. These have been studied by Dr. Marie Stopes, who has published an account of the structure, with special reference to the cones.[1]

The following specimens in the Museum have been figured and described:—

IN THE PALÆONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1916. (PUBLISHED 1918).

The Fossil Fishes of the English Wealden and Purbeck Formations.

By DR. A. SMITH WOODWARD, F.R.S.

Mesodon sp., pl. xiii, f. 4, p. 58.
Coelodus arcuatus *A.S.W.*, pl. xiii, f. 5, p. 70.
Microdon radiatus *Ag.*, pl. xiv, figs. 5, 6, pp. 61, 62.
Coelodus multidens *A.S.W.*, pl. xv, f. 12, p. 68.
Ophiopsis breviceps *Eg.*, pl. xvi, f. 3, p. 74.
Aspidorhynchus fisheri *Eg.*, pl. xx, f. 3, p. 99.
Pholidophorus ornatus *Ag.*, pl. xx, f. 8, p. 105.

A Monograph of the British Palæozoic Asterozoa.

By Mr. W. K. SPENCER, M.A.

Lepidaster grayi *Forbes*, pl. vii, figs. 1–5, p. 117.
Salteraster asperrimus (*Salter*), pl. xi, figs. 3, 4, p. 150.
Salteraster ? imbricatus (*Salter*), pl. xi, f. 5, p. 152.
Salteraster ? coronella (*Salter*), pl. xi, f. 6, p. 153.
Protarthraster longimanus (*Whidb.*), pl. xiii, figs. 3–5, p. 164.

The Pliocene Mollusca of Great Britain.

By MR. F. W. HARMER, M.A.

Cypraea (Erosaria) spurca (*Linné*), pl. xxxiii, f. 8, p. 304.
Sipho latericeus (*Moeller*), pl. xxxvii, f. 14, p. 374.
Raphitoma concinnata (*S. V. Wood*), pl. xxxix, f. 3, p. 382.
" compacta (*E. & B.*), pl. xxxix, f. 7, p. 385.
" hoernesi (*Mayer*), pl. xxxix, f. 8, p. 387.
Admete viridula (*Fab.*) *v.* couthouyi (*Jay*), pl. xxxix, f. 48, p. 407.
Merica contorta (*Bast.*), pl. xl, f. 5, p. 394.
Sveltia lajonkairei (*Nyst*), pl. xl, f. 18, p. 397.
Cerithiopsis metaxae (*Delle Chiaje*), pl. xli, f. 19, p. 422.
" tubercularis (*Mont.*), pl. xli, f. 20, p. 420.
Triforis perversa (*Linné*), *v.* adversa (*Mont.*), pl. xli, f. 25, p. 425.

IN THE PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY OF LONDON, SER. B, VOL. 208.

New Bennettitean Cones from the British Cretaceous.

By MARIE C. STOPES, D.Sc. (Lond.), Ph.D

Bennettites maximus *Carr.*, pl. xxiii, figs. 1, 2, 7; pl. xxiv, figs. 1–6; text-figs. 23, 24, pp. 415–433.

IN THE GEOLOGICAL MAGAZINE, VOL. V. 1918.

By MR. ALFRED BELL.

Astarte kickxi *Nyst*, pl. iv, f. 16 (p. 417 in vol. for 1917).

By MR. T. H. WITHERS,

Pecten sp. (*Pollicipes alatus* of R. Tate), p. 171.

[1] *Phil. Trans. Roy. Soc.*, B, vol. 208, pp. 415–433, 1918.

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SCOTLAND.

As Dr. G. W. Lee was engaged on economic questions, no systematic palæontological work was done beyond the examination of cores from borings for coal and oil-shale. In several cases the results of this work were of direct economic value.

VI.—MUSEUM OF PRACTICAL GEOLOGY.

The Museum remained closed during the year 1918, except for special inquiries.

LIST OF DONATIONS DURING THE YEAR 1918.

ADMIRALTY RESEARCH DEPARTMENT (THROUGH DR. R. BOYLE). Specimens of quartz showing twinning and parallel joint, etc.

BELL, A., ESQ.—A series of casts of Mollusca from the Suffolk Box-stones.

BOILLARD, MONS. M.—A polished and moulded slab of Lunelclair marble and two small slabs of Napolèon marble.

BOYLE, DR. R. (See ADMIRALTY RESEARCH DEPARTMENT).

BRITISH MUSEUM. TRUSTEES OF (THROUGH DR. G. T. PRIOR, F.R.S.)—A series of duplicate samples of Coal, Brown Coal and Peat from a Collection formed by the Austrian Government for the International Exhibition, London, 1862.

CLARK, E. STUART, ESQ.—Two pebbles of quartzite found in the Crown Coal, Llay Hall Collieries, Denbighshire.

DIATOMITE COMPANY, LTD., MESSRS. THE.—A series of samples of diatomite illustrating the products of the Company.

DICK, A.B., ESQ.—Slides and residues of Hampstead Sands. One specimen of slag from Deeside Lead Works, Bagillt, Flint. Two slides of Dr. Stead's (same material).

EDGE, LIEUT. A. BROUGHTON.—Micaceous hæmatite from Kelly Mine, Lustleigh, Devon.

FENTON, S. J., ESQ.—A miner's pick replaced by copper-ore, from Gulf Creek Mine, New South Wales.

FOULKES, LIEUT.-COL., I.M.S.—A series of interesting Alkaline rock specimens from Aden.

FRANCIS, REGINALD, ESQ.—Specimens of Calamine from the English Crown Spelter Company's Mines, Bergamo, Italy.

GREEN, J. F. N., ESQ., B.A.—*Didymograptus v. fractus* (Salter) cf. var. *volucer* Nich. from the Skiddaw Slates of Mungrisdale Quarry, Cumberland.

HALL, LIEUT. T. CLIFFORD, R.E., F.G.S.—A trilobite from the Stiper Stones of Shropshire.

HALLIMOND, A. F., ESQ., B.Sc.—Thirteen specimens of slag, etc., from the Malleable Steel Works, Stockton-on-Tees, also six specimens of slags.

HOLWELL IRON COMPANY, LTD., MESSRS. THE.—Four specimens of Ironstone from the Company's workings.

HONYMAN-GILLESPIE, MRS., TRUSTEES OF THE LATE.—Two polished blocks of Torbanehill Mineral.

HOWLETT, CHARLES E., ESQ., I.S.O. (H.M. OFFICE OF WOODS AND FORESTS).—A small collection of Gold ores from Wales, and a specimen block of Tintern Abbey Stone.

LAMONT, CAPT. A.E., R.A.M.C.—Moderately large specimen of coarse actinolite schist from bed of stream, Paprial Valley, Krusha, Balkan Range, Macedonia.

LAWN, DAVID, ESQ.—A model of the North Pit Ore-body, Park Mines, Dalton-in-Furness. (Made by Herbert Lawn, Esq.)

LOCKHART, W. S., ESQ., M.Inst C.E.—Block of Chinese Chalcedony drilled with the appliances previously presented to the Museum by Dr. Lockhart.

MATHER, R., ESQ.—Specimen illustrating a mode of formation of a volcano.

MICHIE, MRS. A series of mineral specimens from Broken Hill, New South Wales. A series of framed photographs of Broken Hill Mines, and a Show Case.

MUIR, J. M., ESQ.—Seven rock specimens from Oil-field in Mexico, San José de la Rusias. Three specimens of sand from Oil-well. One specimen of basalt from well.

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MURGATROYD, S. L., ESQ.—Calcareous infilling in pipe exhibiting tubular structures, from Brackley, Northants.

OSMAN, CHARLES W., ESQ.—Two specimens of schist, from Wisedom Farm Quarry, Devonshire. Two specimens of Chiastolite Slate from same quarry. Model of interpenetration twin of pyritohedron.

PRIOR, DR. G. T., F.R.S. (*See* BRITISH MUSEUM.)

REDWOOD, SIR BOVERTON, BART., D.Sc., F.R.S.E.—A specimen of peculiar weathering in the oil shale of Watson, Utah, U.S.A.

RONALDSON, R. K., ESQ.—A specimen of Talc from Southern Rhodesia.

RUSSELL, CAPT. A.—Four rock specimens from the lode at Strontian, N.B. Two from Tounnadashan Mine, Loch Tay. Four from Erines Mine, near Tarbert, Argyll. Twelve from Perthshire. Chromite of Coire Charmaig, Glen Lochay, N.B.

SCULLY, GERALD C., ESQ.—Tantalite, spodumene and lepidolite, from the pegmatites near Jackal's Water, N.N.E. of Steinkopf, Namaqualand. Also two crystals of Corundum from mica-schist from same district.

SHERBORN, C. DAVIES, ESQ., F.Z.S., ETC.—A selection of fossils from the Devonian of Cornwall, collected by the late Upfield Green, Esq., F.G.S.

SIMON, DR. A.—Specimens of Antimony Ore, from the Glendinning Mine, Dumfries.

TEALL, SIR J. J. H., F.R.S., ETC.—Two rock specimens (1) Hypersthene Andesite from the Cheviots (2) Dolerite from near Belfast.

TRECHMANN, C. T., ESQ., D.Sc.—Two specimens from Boring from Warren Cement Works, Hartlepool. One specimen from beneath Red beds on north side of Tees near Chemical Works.

WALFORD, E. A., ESQ., F.G.S.—A specimen of Ketton Stone from Stonesfield.

WEARDALE STEEL, COAL AND COKE COMPANY, LTD., MESSRS. The.—A sample of Silica-brick.

WEDD, C.B., ESQ., B.A.—Five fossils from the Cretaceous rocks of Lincolnshire.

WHITAKER, W., ESQ., F.R.S., ETC.—One specimen of Reading Beds containing yellow transparent resin or amber.

WILD, MESSRS. WILLIAM & SONS.—Samples of clay from Voel, the Gate Vein, and the Quarry Vein, Holyhead.

WOODS AND FORESTS, H.M. OFFICE OF (SEE HOWLETT, C.E., Esq.).

VII.—MAPS AND MEMOIRS, ETC., PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

ENGLAND AND WALES.

I.—MEMOIRS.

PUBLISHED MEMOIRS.

Special Reports on the Mineral Resources of Great Britain:—

Vol. III.—Gypsum and Anhydrite. By R. L. Sherlock, D.Sc., and B. Smith, M.A.; and Celestine and Strontianite. By R. L. Sherlock, D.Sc. Second Edition, 64 pp.; 4 text-figures. 1918. Price 2s. net.

Vol. V.—Potash-Felspar—Phosphate of Lime—Alum Shales—Plumbago or Graphite—Molybdenite—Chromite—Talc and Steatite (Soapstone, Soaprock and Potstone)—Diatomite. By A. Strahan, Sc.D., LL.D., F.R.S.; J. S. Flett, D.Sc., LL.D., F.R.S.; and C. H. Dinham, B.A.; with contributions by the late C. T. Clough, M.A., LL.D.; T. Eastwood, A.R.C.S.; and A. F. Hallimond, B.A. Second Edition. 43 pp.; 3 text-figures. 1917. Price 1s. net.

Volume VI.—Refractory Materials: Ganister and Silica-Rock—Sand for Open-Hearth Steel Furnaces—Dolomite Resources and Geology. 233 pp.; 3 plates; 8 text-figures, 1918. Price 7s. 6d. net.

Volume VII.—Lignites, Jets, Kimmeridge Oil-Shale, Mineral Oil, Cannel Coals, Natural Gas. Part I.—England and Wales. By A. Strahan, Sc.D., LL.D., F.R.S., with contributions by J. Pringle. 69 pp.; 1 plate; 3 text-figures. 1918. Price 2s. 6d net.

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Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1917. 55 pp. 1918. Price 2s. net.

The Water Supply of Essex from Underground Sources. By W. Whitaker, B.A., F.R.S., and J. C. Thresh, M.D., D.Sc., D.P.H., F.I.C. The Rainfall, by H. R. Mill, D.Sc., LL.D. 510 pp.; 4 plates. 1916. Price 15s.

SCOTLAND.

I.—MAPS.

(a) One-inch Maps, Colour Printed.

Sheet 74. Solid and Drift Geology. Price 2s. 6d. each.
Sheet 83. Solid and Drift Geology. Price 2s. 6d. each.

(b) Six-inch Reference Maps,

The following copies of six-inch maps have been completed and deposited in the office for reference. These are whole sheets, each consisting of four quarter sheets, except where otherwise stated.

Argyll, 33, 34 N.W., S.W., 47, 48 N.W., S.W.; 61 N.W., N.E. (Island of Oigh Sgeir), 64 N.E., S.E.

Ayr (new series) 55 N.E., S.W., S.E.; 56, 60 S.E.; 61, 62, 63 N.E., S.E.; 66, 69 N.E., S.W., S.E.

Inverness 2 N.E., S.W., S.E.; 3 S.W., S.E.; 4 N.E., S.W., S.E.; 5, 12, 59, 73, 74, 87, 88, 89, 103, 104, N.W., S.W.; 118, 119 N.W., S.W.; 153, 154 S.W., S.E.; 163, 164 N.W., N.E., S.W.; 169 N.W., N.E., Islands of Canna, Sanday, Rum, Eigg and Muck, 53 S.W., S.E., with 54 S.W.; 59 N.W., N.E., S.W.; 69 N.E., 70 N.W., S.E.; 72 N.E., S.W., S.E.; 73 N.W.; 74 N.W., N.E.

Lanark (new series) 25 S.W., S.E.; 32 N.E.

Nairn, 9.

Perth, 9 N.E., S.W., S.E.; 18, 25 N.E., S.E.; 26, 27, 34, 35, 36, 44 N.W., N.E., S.E., with 33a S.E., and 43a N.E.

Ross 77, 78, 100, 101 N.W.

Sheets formerly clean-copied but not reported as deposited, which have now been checked, revised and deposited.

Fife, 3, 4 N.E., S.W., SE.; 5, 6, 7 N.W., S.W.; 8 S.E.; 12, 13 N.W., S.W., S.E.; 14 N.E., S.W., S.E.; 15, 17, 18, 21, 22, 26, 27 N.W.; 38 N.W., N.E.; 39.

Renfrew, 1, 2, 3 N.W., S.W., S.E.; 4 S.W.; 5, 6, 18 N.W., N.E., S.E.; 19.

Stirling, 8 S.W., S.E.; 9 S.W., S.E.; 10, 14, 15, 16, 20, 21, 22, 26 N.W., N.E., S.E.

Dumbarton 15, 17, 18, 19, N.W., S.W., S.E.; 21 N.E.

Ayr, 1, 2, 3, 5, 6, 10 N.E., S.E.; 55, 60, 61, 65, 66, 69.

Wigtown, 4.

II.—MEMOIRS.

PUBLISHED MEMOIRS.

Summary of Progress for 1917. See above.

Special Reports on the Mineral Resources of Great Britain.

Volume V (2nd edition) see p. 35.

Volume VI see p. 35,

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APPENDIX I.

The Faunal Characters and Correlation of the Concealed Mesozoic Rocks in Kent.

By F. L. Kitchin, M.A., Ph.D.

The investigation of Mesozoic fossils obtained from numerous deep borings and a few shaft-sinkings in Kent has been referred to in the three previous issues of the 'Summary of Progress.' Large suites of specimens have been examined during the last few years[1] and the results will appear in a Memoir which will supplement the account of the four sections already published.[2] The present summary of the palæontological results is complementary to an account of the stratigraphy published two years ago.[3] From the sketch-map published there (p. 47) it can be seen that the majority of the newer sections investigated[4] lie to the north of the line Dover-Brabourne. The map also shows the relation of the localities in East Kent to the buried outcrops of the Jurassic formations.

The Triassic rocks, met with in the Brabourne boring only, have proved barren. No fossils have come into our hands from strata overlying the Gault. The specimens studied since 1911 came from formations ranging from the upper zones of the Lower Lias up to the Gault, inclusive. The sequence, however, is incomplete, for part of the Upper Lias and Inferior Oolite is absent by reason of an unconformity, and the upper parts of the Upper Kimmeridge Clay are known only at Pluckley and Penshurst; also, the Purbeck Series has not been proved east of Brabourne, and the Portland beds are present only at Ottinge and farther to the west.

Considering the necessarily imperfect evidence obtainable from the small quantity of rock in the cores, even when supplemented in a few cases by the material from three or four shafts, it is remarkable how clearly the main palæontological features of the separate divisions are recognisable. The great majority of the fossils were the remains of lamellibranchs. Whenever available, ammonites have been utilised as guides to correlation, but in many cases it has been necessary to rely on the imperfectly known bivalves, either singly or collectively, and not without success. Within so limited an area, lateral changes of lithological facies are not so great as to bring about any radical change of faunal

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[1] Mr. G. W. Lamplugh and Mr. J. Pringle examined the materials at the sites: Mr. Pringle has shared with the writer the task of studying the fossils in detail.

[2] 'The Mesozoic Rocks in some of the Coal Explorations in Kent,' *Mem. Geol. Survey*, 1911.

[3] 'The Underground Range of the Jurassic and Lower Cretaceous Rocks in East Kent.' Appendix IV., in 'Summary of Progress' for 1916, *Mem. Geol. Survey*, 1917, p. 45.

[4] We are much indebted to Dr. M. Burr and Mr. E. O. Forster Brown for permission to visit the borings respectively under their charge and, where possible, to make representative collections. In the case of the older Ottinge boring (1898-9) we were not favoured by similar facilities; but by the kindness of Dr. G. Hickling, specimens of the Kimmeridge and Portland rocks from that boring, now preserved in the Manchester Museum, have been placed in our hands for examination.

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characters; indeed, there is a degree of uniformity which has greatly aided correlation. At many horizons the faunas show close agreement with those made familiar at the outcrops in this country. As regards the Jurassic rocks, in some formations there can be recognised close faunal community with Continental deposits, be it the nearer developments in France and Switzerland or the more distant representatives in Russia.

The conditions are different when we study the fossils with reference to vertical succession and zonal delimitation. Successive beds or groups of beds showing marked lithological changes frequently exhibit faunal contrasts more abrupt than would result merely during the passage of time. Faunal characterisation may thereby become accentuated, introducing a certain relief as between contiguous strata; and this sometimes compensates for the scantiness of the usual criteria for zonal subdivision.

The evidence of fossils has enabled us to gauge the magnitude of the unconformities shown in the sections. Thus it has been possible to prove the varying position in the Upper Lias at which the Lias-Oolite unconformity occurs, and to demonstrate that the basal sands of the Oolite Series are of Inferior Oolite age at Dover, but of Great Oolite age at Snowdown and Bere Farm. Similarly, we have been enabled to determine precisely the position at which the upward sequence in the Jurassic series is interrupted by the unconformable junction with the Wealden Beds, a descending line when traced in a north-easterly direction. The fossils, again, have revealed a well-marked break above the Kimmeridge Clay at Ottinge and Brabourne, involving the absence there of the higher parts of the formation and probably of some basal portion of the Portland Beds also. The palæontological evidence, in providing a key to the true reading of the Kimmeridge Clay, has rendered it possible to show further that the easterly thinning of the formation is due only in part to a true attenuation, and is largely attributable to erosion of the upper portions, as shown at Abbotscliff and Dover. The influence of the two factors can be estimated with approximate accuracy, a result that was unattainable on lithological evidence. In the Cretaceous rocks the fossil-evidence suggests that some lower part of the Atherfield Beds is absent and that, north-east of Folkestone, there is also a non-sequence between the Atherfield Clay and the Sandgate Beds above. Similarly there is evidence, chiefly of a negative character, to suggest the existence of a break between the Folkestone Beds and the Gault.

In the present sketch it is possible only to indicate briefly the chief characteristics of successive beds and the principal evidence on which our correlations have been based. The presentation of fuller detail is reserved for the forthcoming Memoir.

Lias.—This formation is found everywhere to be imperfect, though there is almost always some representation of the Lower, Middle and Upper subdivisions. There is a remarkable condensation in an easterly and north-easterly direction, as shown at Dover, Bishopsbourne and Fredville. The lowest beds at Brabourne may be ascribed to the Jamesoni Zone. They are poorly characterised

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by fossils, but this correlation is strongly suggested by the presence of *Rhynchonella rimosa* (v. Buch) and *Lima antiquata* J. Sow., and of ?*Polymorphites trivialis* (Simps.) a little higher up. The ferruginous basement-bed at Folkestone, yielding *Lima antiquata*, may belong to the same zone, while the presence of *Rhynchonella rimosa* and *Lima antiquata?* in the base of the much-condensed Lower Lias at Dover suggests a similar correlation there. At most localities the base is not below the Capricornus Beds, which are palæontologically well characterised in Kent. These clays have yielded *Androgynoceras maculatum* (Y. and B.), *A.* cf. *lataecosta* (J. de C. Sow.) and *Oistoceras arcigerens* (Phill.). The numerous bivalves include small well-ribbed species of *Astarte*, *Grammatodon intermedius* (Simps.), a characteristic *Nuculana* and *Unicardium cardioides* Phill. A *Spiriferina* resembling *S. rostrata* (Schloth.) occurs locally. At Chilton there is great condensation, with a basal limestone-band containing rolled specimens of *Montlivaltia*.

The Middle Lias comprises a thin shaly member in its lowest part, which may be allocated to the Margaritatus Zone, and a thicker limestone-series above, ascribable in the main to the Spinatus Zone. No ammonites have been seen and the zonal junction cannot yet be fixed. The Margaritatus-shale contains a bivalve-fauna which includes *Modiola scalprum* J. Sow., *Myoconcha decorata* (Münst.), *Protocardia truncata* (J. de C. Sow.) and an undescribed *Nuculana* characteristic of the same zone in the Midlands. A shallowing of the sea at the close of Capricornus-time is shown at Chilton by a pebbly bed at the base of the Middle Lias, while the absence of the Margaritatus-shale marked a break in deposition at Harmansole. The limestone-series above is always characterised by *Pecten aequivalvis* J. Sow., *P. liasianus* Nyst and abundant Rhynchonellids. These include *Rhynchonella capitulata* Tate, found only in the Spinatus Zone elsewhere; but the more common species are *R. fodinalis* Tate, *R. northamptonensis* Dav., *R. tetrahedra* (J. Sow.) and comparable forms. *Belemnites breviformis* Voltz was also met with. An unusual feature is the rarity of Terebratulids.

At Harmansole the Lias-Oolite unconformity cuts down to the Middle Lias. At Chilton and Fredville it occurs a little higher, so that there is a thin capping of sandy limestone representing the Annulatus Zone (Acutum + Tenuicostatum), which is very scantily developed throughout the area. Lithologically continuous with the underlying beds, it is marked off by the sudden appearance of *Dactylioceras tenuicostatum* (Y. and B.) and similar finely-ribbed forms. The overlying lowest member of the Serpentinus Zone is developed as a clay or clay-shale, as seen at Bishopsbourne, Dover, Elham, Folkestone and Ropersole; it may be correlated with the Exaratum Zone of Mr. Buckman. The ammonites include *Dactylioceras delicatum* (Simps.), while the chief associated fossils are *Orbiculoidea reflexa* (J. de C. Sow.), an undescribed oyster and a *Corbula*, abundant and characteristic of the bed. A higher level in the Serpentinus Zone (Falcifer-Pseudovatum beds of Mr. Buckman) is represented at Bishopsbourne, Elham and Folkestone. Here were found *Harpoceras mulgravium* (Y. and B.), *H.* cf. *strangewaysi* (J. Sow.), *Hildoceras*

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levisoni (Simps.), *Dactylioceras spp.* and *Belemnites subtenuis* (Simps.). At Brabourne and Elham a still higher bed represents the Communis Zone (Subcarinatum-Fibulatum of Mr. Buckman), with a species of *Dactylioceras* comparable with *D. commune* (J. Sow.), *Hildoceras walcotti* (J. Sow.), *Peronoceras attenuatum* (Simps.) and *Porpoceras andraei* (Simps.). Mr. Buckman has considered that a still higher zonal level is reached below the unconformity at Brabourne, as indicated by a *Grammoceras* resembling *G. striatulum* (J. de C. Sow.).

Inferior Oolite.—It was suggested in the Memoir of 1911 that some basal part of the Oolites at Dover and Brabourne might be correlated with the Inferior Oolite. Fossils obtained at Dover have since provided the desired proof. In the lowest sandy beds an abundant bivalve-fauna has been found, pointing to a position within the Parkinsoni Zone. Among 25 species collected from shaft-material, there occurred abundantly such typical shells as *Gresslya abducta* (Phill.) and *Pholadomya fidicula* J. Sow., as well as *Opis* (*Pachyopsis*) *cordiformis* Lyc. There were also some *Trigoniae* of the *duplicata*-group, suggesting a position in the Garantiana Zone or perhaps a little higher. No ammonites were seen. Many of the lamellibranch-shells show pronounced abrasion. The lowest few feet of Oolites with sandy base at Elham also probably belong to the Inferior Oolite.

Great Oolite and Forest Marble.—The lowest part of this series is represented at Brabourne and Elham by shales and limestones of Fullonian type, but eastwards, at Fredville and Bere Farm, in closer proximity to the shore-line of the period, the basal beds become more sandy. At Elham the lowest beds yielded *Trigonia signata* Ag., indicating a Lower Fuller's Earth horizon (of *zig-zag—fusca* age); there occur also abundant specimens of *Pteria* (*Oxytoma*) *inequivalvis* (J. Sow.) and a coarsely-ribbed *Astarte*, as in the corresponding deposits at Brabourne. The sandy beds at Fredville and Bere Farm also appear to occupy a position below the Fuller's Earth Rock. They contain an abundant fauna, chiefly bivalves, including some common forms of the Great Oolite. *Thamnastraea lyelli* Edw. and Haime and *Rhynchonella lotharingica* Haas were also found, the latter pointing to a position within the *zig-zag—acuminata* beds; a *Pleuromya*, abundant also in the Lower Fuller's Earth of Wiltshire, supports the correlation. *Homomya gibbosa* (J. Sow.) and *Pholadomya murchisoni* Moesch, well suited to the sandy conditions, are common at Fredville (Snowdown shaft).

A slightly higher zonal level is represented by the limestones and sandy beds at Tilmanstone, Maydensole and Oxney, as indicated by *Ostrea acuminata* J. Sow. and *Trigonia clavulosa* Rig. and Sauvage. Thus, as we pass in a north-easterly direction from a line drawn between Elham and Dover Colliery, not only is the Inferior Oolite absent, as at Bere Farm, Chilton and Fredville, but the base of the Oolites occurs at a rising level in the series. At Betteshanger, north-east of Tilmanstone, the lowest Oolite beds approximate in type to those in the higher part of the Great Oolite throughout the district. Above the *acuminata*-horizon zonal indications are scanty; but there is a transition through beds with *Rhynchonella* cf. *hopkinsi* Dav. up to purer

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oolite-limestones with *Terebratula bathonica* (S. Buckm.). Fossils are sparingly present, on the whole.

The more impure and variable beds of the Forest Marble contain a bivalve-fauna continuing the general characters of that in the limestones below. But here we find *Gervillia crassicosta* Morr. and Lyc. at its maximum, both in respect to numbers and the size of the valves, while distinctive faunal elements are provided by *Terebratula marmorea* Opp., *Astarte fimbriata* Lyc. and *Perna obliqua* Lyc., with undescribed species of *Modiola* and *Astarte* unknown at other zonal levels.

Cornbrash.—This formation is developed as a series of limestones, some of which are rubbly, with a band of clay at the top. It is palæontologically well marked off from the Forest Marble. *Macrocephalites* was found in the limestones up to the base of the clay. The lower beds are highly fossiliferous, with a characteristic assemblage of species such as *Echinobrissus clunicularis* Wright, *E. orbicularis* (Phill.), *E. quadratus* Wright (common in this area), *Holectypus depressus* (Leske), *Microthyris lagenalis* (Schloth.), *Ornithella obovata* (J. Sow.), *Rhynchonella major* Desl. [*non* Sow.] and *Terebratula intermedia* J. Sow. The many associated lamellibranchs included *Pseudomonotis echinatus* (J. Sow.), typical in its abundance and robustness of type. The argillaceous bed at the top showed an absence of echinoids and rarity of brachiopods. Its bivalve-fauna is chiefly characterised by *Pholadomya phillipsi* Lyc. and an abundant *Pseudomonotis*, differing from the typical *Ps. echinatus* by weaker inflation and less strong and spinous ribbing.

Kellaways Rock.—A somewhat abrupt transition to the sandy and ferruginous Kellaways beds is accompanied by a marked faunal change. Only at Oxney, where *Proplanulites* was found at the base, was there definite representation of the Koenigi Beds, and the fact that no specimen of *Kepplerites* has anywhere been seen also points to the local absence or imperfect development of that zone. At most localities the formation is characterised throughout by a bivalve-fauna of relatively few species, though with a profusion of individuals. The commoner are gryphæate oysters of several stocks and an undescribed *Pseudomonotis*, larger than *Ps. echinatus*. The oysters are mostly of small size in the lowest beds, with an increasing proportion of larger individuals at successively higher levels. The large and abundant *Gryphæa bilobata* J. de C. Sow. is dominant in the upper beds. Ammonites are rare and include *Sigaloceras calloviense* (J. Sow.) and some forms of '*Cosmoceras*' similar to specimens which occur in the Calloviensis Zone of Wiltshire. The top bed has yielded numerous examples of *Belemnites oweni* Pratt.

Oxford Clay.—The marly clays of the 'Ornatus Beds' are characterised by brown-coated casts of *Cosmoceras* throughout. Finely ribbed forms commonly referred to *C. jason* (Rein.) occur at the base. *Erymnoceras* was found a few feet higher, suggesting a *coronatum*-horizon, while *Cosmoceras duncani* (J. Sow.) and *C. castor* (Rein.) occurred just above this. There is no sign of the *Reineckeia*-fauna (Anceps Zone) below or the Athleta Zone above. The clay contains innumerable casts of lamellibranchs, including undescribed species of *Astarte*, *Cucullaea* and *Nucula*.

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In the purer clays of the 'Renggeri Beds' fossils occurred more sporadically. *Quenstedtoceras* replaces *Cosmoceras* and is represented by *Q. macrum* (Quenst.), *Q. leachi* (J. Sow.), *Q. lamberti* (J. Sow.) and others. *Creniceras crenatum* (Brug.), *C. cristatum* (J. de C. Sow.) and species of *Hecticoceras* are characteristic. Some of the bivalves, such as *Grammatodon concinnus* (Phill.), *G. montaneyensis* (de Lor.) and *Nuculana roederi* (de Lor.), help to show the faunal connection with corresponding beds in the Bernese Jura.

In the highest part of the Oxford Clay ('Mariae Beds') the *Quenstedtoceras*-fauna is continued, but *Creniceras* and *Hecticoceras* are absent. There are specimens of *Perisphinctes* resembling *P. matheyi* de Lor. and *P. moeschi* de Lor. (Bernese Jura). The bivalve-fauna appears similar to that of the middle sub-division, but is more imperfectly known.

Corallian Series.—The lowest 25 ft.—35 ft. of this series are ferruginous and yield a *Cardioceras*-fauna including *C. nikitinianum* Lahus., *C. rouillieri* Lahus., *C. tenuicostatum* (Nik.) and others of Russian facies belonging to Pre-*cordatus* time. There are many associated bivalves, and towards the top of these ferruginous marlstones the presence of *Millericrinus*-stems recalls the corresponding 'Marnes à *Millericrinus*' near Boulogne. The succeeding grey limy marls show in their lower part a thin echinoid-bed with *Echinobrissus* and *Holectypus*, a large *Gryphaea* and *Perisphinctes variocostatus*? (Buckl.). This can be widely traced and is followed above by a conspicuous grey marlstone-band full of black-coated casts of shells, including *Perna cordati* Uhl., *Aspidoceras*, *Peltoceras arduennense* (d'Orb.) and *P.* cf. *eugenii* (d'Orb.). Correlation may be made with Hébert's Bed 15 in the section at Villers-sur-Mer. The fauna of the true Cordatus Zone (or Vertebrale Zone) has not been detected in Kent.

The limestones constituting the middle part of the formation contain *Cidaris florigemma* Phill. throughout. In their lower part they yield typical corals, with *Hemicidaris intermedia* (Flem.), *Glypticus hieroglyphicus* (Goldf.), *Ornithella delmontana* (Oppel) and *Pseudomelania heddingtonensis* (J. Sow.), among other fossils, recalling the 'Glypticien' in the Haute-Marne district. These beds merge up into purer cream-coloured limestones of 'Coral Rag' type, with abundant corals and a varied gasteropod-fauna in which *Nerinea tuberculosa* Defr. is most conspicuous.

The variable upper beds yield *Amoeboceras* in their lower part, while the 'millet-seed' ironstone falls in the Ringsteadia Zone, thus corresponding with the Westbury ironstone. Below it was found *Belemnites nitidus* Dollf.[*non* Phill.], a species of the Decipiens and Ringsteadia Zones elsewhere. The uppermost bed yielded only a bivalve-fauna with few zonal characteristics; but we believe the upper limit to fall at about the base of Salfeld's Zone of *Pictonia baylei*.

Kimmeridge Clay.—The Lower Clays, with *Exogyra virgula* (Defr.) and its smaller forerunners, comprise the Pictonia Beds up to the Gravesia Beds, inclusive. They yield *Ostrea deltoidea* J. Sow., *Gervillia kimmeridgensis* d'Orb., *Nucula menkei* F. A. Roem. and *Pecten kimmeridgensis* Cott. in their lowest part.

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At 10 ft.—30 ft. above the base the *Rasenia*-fauna is found, with *Physodoceras orthocera* (d'Orb.) and '*Holcostephani*' of earlier authors, such as '*H.*' *witteanus* (Opp.) and close congeners of '*H.*' *stephanoides* (Opp.) and '*H.*' *trimerus* (Opp.). The Rasenia Beds are developed in Dorset, in Lincolnshire (Market Rasen) and in Northern France (the Orthocera Beds); they correspond with the Tenuilobatus Zone (*s. str.*) of Crussol in Ardèche and Baden in Switzerland. The first appearance of *Protocardia morinica* (de Lor.) occurs some distance higher up, marking a position in the Aulacostephanus Zones of Salfeld's scheme. *Exogyra virgula* (Defr.) becomes increasingly large and abundant when traced upwards. It ranges probably to the top of the Gravesia Beds of Salfeld, marked by the Yellow Ledge at Kimmeridge. At Lower Standen the top of the Lower Clays has yielded *Gravesia* and a *Perisphinctes* resembling *P. bleicheri* (de Lor.), supporting the correlation. *Orbiculoidea latissima* (J. Sow.) is rare in the lower part of the Gravesia Beds but common near the top, though of smaller size than in higher zones. At Dover the eroded top of the Kimmeridge Clay falls just above the Rasenia Beds, but at Abbotscliff it is well up in the Aulacostephanus Beds. The Lower Clays are complete at Lower Standen and to the west, and thicken rapidly in that direction.

The Upper Clays, containing *Modiola autissiodorensis* but not *Exogyra virgula*, comprise the Virgatites Zone and higher beds up to the base of the Portland Stone Series, the deeper water argillaceous facies persisting in this area when Portland Sands are developed elsewhere. The Virgatites Beds are perhaps represented by their basal part at Elham. The whole of the zone is present at Ottinge and Brabourne, and perhaps also the base of the Pallasianus Zone; but an unconformity there cuts off the higher beds, as in Lincolnshire and Yorkshire. The Upper Clays are in full development at Pluckley and Penshurst, where they have thickened greatly.

The Virgatites Zone is characterised by small coarsely-ribbed forms of *Astarte*, *Lucina minuscula* Blake, *Modiola autissiodorensis* (Cott.), *Protocardia morinica* (de Lor.), an abundant undescribed *Aporrhais*, an undescribed *Cyprina* and other bivalves. *Pecten morini* de Lor. comes in at about the top and is commoner above. Some of the fragments of ammonites seen in the boring-cores appear to belong to *Pseudovirgatites* and *Virgatosphinctes*, and may include the true *Virgatites*, as in Dorset. There is also a small, delicately ribbed involute Perisphinctoid, common in the zone elsewhere. An important datum-line is furnished by the minute pyritized radial plates of the pelagic crinoid *Saccocoma*, seen at Penshurst (at 1,794 ft.—1,806 ft. depth), and since found by Mr. Pringle to characterise the Oil-Shale horizon at Corton and the Blackstone band and about 15 ft. of shales below it at Kimmeridge. The abundance and well defined vertical distribution of the plates in the two districts justifies us in establishing a Sub-zone of *Saccocoma*.

The Pallasianus Zone was best seen in its thick development at Penshurst (at about 1,300 ft.—1,500 ft. in depth). Numerous ammonites, fragmentary as preserved in the cores, indicate a well developed cephalopod-fauna of Russian facies, permitting com-

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parison with '*Holcostephanus*' *pallasianus* (d'Orb.), '*H.*' *panderi* (d'Orb.) and Michalski's figures of '*H.*' *lomonossovi*, '*Perisphinctes*' *stschukinensis* and other species. Two characteristic bivalves are a new *Grammatodon* and *Cyprina implicata* de Lor. The beds representing the higher zones yielded few fossils, and the data are insufficient for the purpose of subdivision. A fragment of a large '*Perisphinctes*' may possibly belong to '*P.*' *giganteus* (d'Orb.); among the bivalves there occurred *Ostrea bononiae* Sauvage.

Portland and Purbeck Beds.—The Portland Series, equivalent to the Upper Portland Beds of Dorset, is thickest at Penshurst and diminishes eastwards as shown at Brabourne and Ottinge. This is due partly to attenuation, but also, we believe, to the absence of some of the lower beds at those localities (where there is an unconformable base), a view supported by lithological evidence. Remains of *Perna* were numerous near the base at Penshurst but absent at the easterly localities. Ammonites found in the lower parts of the series at Brabourne and Penshurst are large specimens of '*Perisphinctes*,' incomplete in the cores. Comparison is permissible with '*P.*' *bononiensis* (de Lor.), '*P.*' *giganteus* (d'Orb.) and '*P.*' *giganteus* (J. Sow.). The bivalves, more numerous in the higher part of the series, include *Pecten* (*Camptonectes*) *lamellosus* J. Sow., *Modiola boloniensis* de Lor., *Pleuromya tellina* Ag. and *Trigonia gibbosa* J. Sow. The available data are insufficient for zonal subdivision.

No new information is forthcoming concerning the Purbeck Beds. The fresh-water strata, as previously described, contain the usual fauna of ostracods, *Cyrena*, *Unio* and *Viviparus*, while marine incursions about the middle part of the series are indicated, as in Dorset, by *Corbula alata* J. de C. Sow., *Ostrea distorta* J. de C. Sow., *Protocardia purbeckensis* (de Lor.) and other species.

Wealden and Lower Greensand.—The newer explorations have thrown no fresh light on the palæontology of the Wealden Beds.

The Atherfield Clay was penetrated in most of the borings, but cores were seldom available. Nearly all the fossils obtained had already been noted at Dover. The basal Perna Bed appears to be unrepresented. Ammonites of the *deshayesi*-group are distributed throughout the clay, and the association of species found in this deposit points to a correlation with the Lower Aptian (Bedoulien) of Kilian's classification.

Hythe Beds are probably present at Folkestone though absent farther east, where greensand of Sandgate type rests on the floor of Atherfield Clay and fills the numerous burrows of boring molluscs which penetrate it. Fossils found in the Sandgate Beds of the newer borings include *Rhynchonella latissima* (J. de. C. Sow.), *Trigonia caudata* Ag. and the rare *Anthonya cantiana* Woods.

No constant line can be drawn between the Sandgate and Folkestone Beds on palæontological evidence. Beds of Folkestone character vary in thickness according to local conditions, and beyond *Exogyra sinuata* (J. Sow.), they have yielded few fossils. A comparison with Continental deposits shows that the

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faunal representation is imperfect and suggests that the sequence is incomplete at the top.

Mammillatus Bed and Gault.—The lamellibranchs of the Mammillatus Bed comprise well-known species of the Gault, while the presence of ammonites of the groups of *Hoplites raulinianus* (d'Orb.) and *H. interruptus* (Brug.) strengthens the alliance with the clay above. Although the Mammillatus Bed is a condensed deposit, it probably represents only some upper portion of the strata on the Continent characterised by *Douvilleiceras mammillatum* (Schloth.) In Brunswick and South-Eastern France the lower part of the beds containing that species constitutes the Zone of *Leymeriella tardefurcata* (Leym.), marked by a distinctive ammonite-fauna of which no trace has been seen in Kent; this lower zone is also unrepresented in the Boulonnais. These facts further suggest the existence of a non-sequence between the Folkestone Beds and the Mammillatus Bed in Kent.

The few available boring-cores from the Gault Clay have yielded some of the typical fossils known at the outcrop, calling for no comment.

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APPENDIX II.

List of the Fossil Plants from the Coal Measures of the Borings at Bere Farm, Elham, Folkestone, and Lydden Valley, Kent.[1]

By Dr. R. Kidston, F.R.S.

Elham Boring, Elham, Kent.

Coal Measures entered at 1,598 ft.

Depth in feet.	
1,720, 2,162	Sphenopteris sp.
2,254	Alethopteris lonchitica *Schloth. sp.*
1,720	Lonchopteris rugosa *Brongn.*
1,975	Mariopteris muricata *Schloth. sp.*
1,845, 2,030	Neuropteris gigantea *Sternb.*
2,030	„ heterophylla *Brongn.*
2,032	„ microphylla *Brongn.*
2,118, 2,122...	„ tenuifolia *Schloth. sp.*
1,975, 2,030, 2,176... ...	„ spp.
1,944, 1,946	Calamites suckowi *Brongn.* [Rhizome]
2,074	*Cf.* Calamites suckowi *Brongn.*
1,820	Calamites undulatus *Sternb. sp.*
2,190	Calamitic cone
1,720	Asterophyllites equisetiformis *Schloth. sp.*
2,160	Sphenophyllum sp.
1,706	Lepidodendron sp.
1,706, 1,709	Lepidostrobus anthemis *König sp.*
1,726	Sigillaria laevigata *Brongn.*
1,744, 2,044, 2,196... ...	Stigmaria ficoides *Sternb. sp.*
1,720	Cordaites principalis *Germar sp.*
1,720	Carpolithus membranaceus *Göpp.*

The number of species identified from this boring is small, but the rocks from which they have been derived appear to belong to the Westphalian Series.

Bere Farm Boring, 1¾ miles N.E. of Dover.

Coal Measures entered at 1,358 ft.

Depth in feet.	
1,994	Sphenopteris *cf.* neuropteroides *Boulay sp.*
1,880–1,886...	Pecopteris *cf.* unita *Brongn.*
1,880–1,886, 2,684–2,690 ...	„ miltoni *Artis sp.*
1,994	„ *cf.* miltoni *Artis sp.*
2,684–2,690	„ *cf.* pennæformis *Brongn.*
2,684–2,690	„ *cf.* richardsoni *D. White* [Geol. of McAlester-Lehigh Coal Field Indian Territory. Report on the Fossil Plants. U.S. Geol. Survey 19th Ann. Rept., part iii, 1899, p. 492, pl. lxviii, figs. 2, 4, 3a, 4a.]
1,880–1,886, 2,550, 2,684–90	Pecopteris (Cyatheites) spp.
2,684–2,690...	Mariopteris muricata *Schloth. sp.*
2,684–2,690...	„ sp.
1,880–1,886, 2,055–2,056 ...	Alethopteris davreuxi *Brongn. sp.*
1,880–1,886...	Neuropteris macrophylla *Brongn.*
1,970	„ *cf.* macrophylla *Brongn.*
1,880–1,886, 1,970, 1,994, 2,005–2,008, 2,911, 2,924, 2,984–2,990, 2,630–2,635	„ scheuchzeri *Hoffm.*

[1] For a brief account of the first three of these sections see 'Summary of Progress' for 1916, *Mem. Geol. Surv.* 1917, p. 34.

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Depth in feet.	
2,634–90	Neuropteris missouriensis *Lesqx.*
1,880–1,886, 2,550, 2,684–2,690	„ ovata *Hoffm.*
2,630–2,635...	„ obliqua *Brongn. sp.*
1,975, 1,995, 2,348, 2,630–2,635, 2,911	„ rarinervis *Bunbury*
1,880–1,886, 2,684–2,690, 2,924, 2,944	„ *cf.* rarinervis *Bunbury*
2,550, 2,911	„ microphylla *Brongn.*
2,630–35, 2,684–2,690, 2,944	„ spp.
2,944	Odontopteris lindleyana *Sternb.*
1,880–1,886, 2,005–2,008 ...	„ *cf* lindleyana *Sternb.*
2,944	Linopteris munsteri *Eichw. sp.*
1,944	Aphlebia sp.
1,926, 1,950, ...	Calamites suckowi *Brongn.*
1,990	„ *cf.* suckowi *Brongn.*
1,920, 2,684–2,690... ...	„ sp.
1,880–1,886, 2,684–2,690, 2,944	Annularia sphenophylloides *Zenker sp.*
1,880–1,886	„ stellata *Schloth. sp.*
1,880–1,886, 2,081... ...	Cordaianthus spp.
2,005–2,008...	Palaeostachya elongata *Presl. sp.*
1,880–1,886, 2,005–2,008 ...	Sphenophyllum emarginatum *Brongn.*
2,684–2,690...	Sigillaria tessellata *Brongn.*
1,864, 2,754	Stigmaria ficoides *Sternb. sp.*
2,911	Cordaites palmæformis *Göpp. sp.*
1,880–1,886, 2,085... ...	„ sp.
1,920	Samaropsis arberi *Kidston* n. sp. [*Cornucarpus acutus* Arber (*non* L. and H. sp.) *Annals of Bot.*, vol. xxviii, p. 97, pl. vi, fig. 14 and text fig. 2, 1914.]
1,880-1,886...	*Cf.* Trigonocarpus sp.

The rocks passed through in the uper part of this bore, from 1,864 ft. to 2,085, are referable to the Keele Group of the Radstockian Series, and from 2,348 ft. to 2,944 ft. to the Etruria Marl Group of the Staffordian Series.

Owing to our imperfect knowledge of the fossil plants of the Staffordian Series, the zoning of these rocks offers considerable difficulty, but the flora observed between the depths of 2,348 ft. and 2,944 ft. seems to indicate a higher horizon than the Black-band Group of the Staffordian Series.

If the Newcastle Group is present, it must lie between the depths of 2,085 ft. and 2,348 ft., from which no fossil plants have been collected.

Boring at Tower Brickworks, Folkestone, Kent.

Coal Measures entered at 1,487 ft.

Depth in feet.	
1,780, 2,072	Sphenopteris obtusiloba, *Brongn., forma* convexiloba *Schimper*
1,768, 1,980...	„ chærophylloides *Brongn. sp.*
1,636	„ *cf.* artemisiætolioides *Crépin*
1,768	„ herbacea *Boulay*
1,585, 1,792–1,795... ...	„ sp.
1,590, 1,996, 2,914... ...	Eremopteris artemisiæfolia *Sternb. sp.*
1,636	*Cf.* „ „ „
1,980, 2,950–2,955, 3,095–3,097	Pecopteris miltoni *Artis sp.*
1,760	„ oreopteridia *Schloth. sp.*
2,950–2,955...	„ bucklandi *Brongn.*

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Depth in feet.	
1,548–1,552, 1,590, 1,678, 1,764, 1,980, 2,044, 2,990–2,993, 3,290	Pecopteris (Cyatheites) sp.
1,620, 3,095–3,097... ...	Dactylotheca plumosa *Artis sp.*
1,784–1,787	Mariopteris muricata *Schloth. sp.*
1,647–1,649, 1,784–1,787 ...	„ „ „ *forma* nervosa *L. and H., pro sp.*
1,647–1,649	„ sp.
1,690–1,715	Alethopteris serli *Brongn. sp.*
1,715, 2,072	„ aquilina *Schloth. sp.*
1,760	Odontopteris *cf.* lindleyana *Sternb.*
1,548–1,552, 1,647–1,649, 1,780, 1,784–1,787, 1,792–1,795, 1,846, 1,980, 2,019, 2,044, 2,635–2,640, 2,990–2,993, 3,290, 3,298	Neuropteris scheuchzeri *Hoffm.*
1,647–1,649, 1,837–1,840, 1,846	„ flexuosa *Sternb.*
1,647–1,649...	„ „ „ *forma* rotundifolia *Brongn. pro sp.*
1,792–1,795, 1846	„ fimbriata *Lesqx.*
1,548–1,552, 1,690, 1,708–1,710, 1,780, 1,784–1,787, 1,792–1,795, 1,780, 1,873, 2,242, 2,765, 2,790	„ rarinervis *Bunbury*
2,780	Neuropteris *cf.* callosa *Lesqx.*
1,792–1,795...	„ ovata *Hoffm.*
2,760	„ *cf.* grangeri *Brongn.*
1,846	„ gigantea *Sternb.*
1,837–1,840...	„ sp. [*N. squarrosæformis* Kidston MS.]
1,647–1649, 1,837–1,846, 1,980, 2,806, 2,950–2,955, 2,990–2,993, 3,286, 3,295	„ spp.
1,548–1,552, 1,585, 1,620, 1,647–1649	Calamites suckowi *Brongn.*
1,536, 1,548–1,552, 1,620, 1,784–1,787, 1,816, 2,483–2,484, 2,890	„ spp.
1,548–1,552, 1,747	Calamitic cone.
1,747	Annularia galioides *L. and H. sp.*
1,647–1,649, 1,708–1,710, 1,715, 1,873, 1,969, 1,980, 2,826, 2,950–2,955, 3,095–3,097	„ sphenophylloides *Zenker sp.*
1,708–1,710, 1,980, 2,284, 2,635–2,640	„ stellata *Schloth. sp.*
1,780	„ *cf.* „ „
1,660	Asterophyllites longifolius *Sternb. sp.*
1,792–1,795...	Stachannularia tuberculata *Sternb. sp.* [axis of cone]
1,647–1649, 1,980, 2,044 ...	Sphenophyllum emarginatum *Brongn.*
1,780	„ majus *Bronn sp.*
1,590, 1,980	„ sp.
1,846	Lepidodendron fusiforme *Corda*
1,846	„ rimosum *Sternb.*
1,784–1,787, 2,019	„ sp.
1,780, 3,095–3,097	Lepidophyllum anthemis *König sp.*
1,980	„ lanceolatum *L. and H.*
1,792–1,795	Lepidophyllum majus *Brongn.*
1,780, 2,635–2,640... ...	„ sp.
1,980	Lepidostrobus sp.
2,019	Sigillaria sp.
2,019, 3,095–3,097... ...	Sigillariophyllum sp.
1,578	Stigmaria ficoides *Sternb. sp.*

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Depth in feet.	
1,708–1,710, 1,950...	Cordaites borassifolius *Sternb. sp.*
1,748, 1,750, 1,980...	„ *cf.* palmaeformis *Göpp. sp.*
1,490, 1,768	„ sp.
2,591	Dadoxylon sp.
1,715	Carpolithus membranaceus *Göpp.*
1,647–1,649	Holcospermum mamillatum *Lesqx., sp.* [*Rhabdocarpus mamillatus*, Lesqx., Coal Flora, vol. iii, p. 816, pl. cx, figs. 39–42, 1884]
2,242	Samaropsis arberi *Kidst.* [*Cornucarpus acutus* Arber (*non.* L. and H. sp.). *Annals of Bot.*, vol. xxviii, p. 97, pl. vi, fig. 14 and text fig. 2, 1914.]
1,980	Samaropsis crassa *Lesqx.*
1,715	„ reniformis *Geinitz sp.* [*Cardiocarpon reniforme* Geinitz. Leitpflanzen des Rothl. u. d. Zechsteingebirges oder d. perm. Formation in Sachsen, p. 18, pl. ii, figs. 15, 16, 1858]
1,764	Samaropsis fluitans *Auctt.* [*non* Dawson]

The rocks passed through in this bore from 1,490 ft. to 3,298 ft. are referable to the Staffordian Series. The zoning of this series, as already mentioned, is extremely difficult, but I am inclined to refer provisionally the portion of the bore comprised in the above list, to the Etruria Marl Group.

Among the plants collected from this bore are two, new to Britain—*Samaropsis reniformis* Geinitz sp., at a depth of 1,715 ft., a seed originally described from the Permian, and *Sphenopteris herbacea* Boulay (Le terr. houil. du Nord de la France et ses végétaux fossiles, p. 27, pl. i, fig. 5. 1876), at a depth of 1,768 ft., a species which occurs in the Westphalian of France and Belgium.

Another species, *Neuropteris squarrosæformis* Kidston MS.—not yet described, is also represented by a single specimen which occurred at a depth of 1837—40 ft. It has previously been found in the Blackband Group of the Staffordian Series of Staffordshire and in the Westphalian of Yorkshire. *Holcospermum mamillatum* Lesqx. sp., from a depth of 1,647-1,649 ft., has also previously been met with in the Blackband Group of North Staffordshire, but the record has not yet been published.

Lydden Valley Boring, near Deal, Kent.

Coal Measures entered at 939 ft.

Depth in feet.	
1,505, 1,798	Neuropteris gigantea *Sternb.*
942–945	„ obliqua *Brongn. sp.*
..	„ rarinervis *Bunb.*
1,063	„ scheuchzeri *Hoffm.*
1,792	„ sp.
1,560	Calamites sp.
942-945	Annularia stellata *Schloth. sp.*
1,406, 1,560	Asterophyllites equisetiformis *Schloth. sp.*
942–945	Sphenophyllum emarginatum *Brongn.*
1,063	Sigillaria sp.
1,542½–1,545	Cordaicladus sp.
1,798	Cordaianthus volkmanni *Ett. sp.*

The upper part of this boring from 942 ft. to 1,063 ft., I would refer provisionally to the Blackband Group of the Staffordian Series, and from 1,406 ft. to 1,798 ft. to the Westphalian Series.

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APPENDIX III.

Palæontological Notes on the Donnington Borehole of 1917.

By J. Pringle.

This borehole is described in 'Special Reports on the Mineral Resources of Great Britain,' vol. vii, *Mem. Geol. Survey*, 1918, pp. 39, 40. It was situated on the outcrop of the Tealby Clay, but no cores were obtained until the underlying Claxby Ironstone was reached at a depth of 44 ft.

Claxby Ironstone.—This bed, represented for a thickness of 4 ft., consisted of small brown spherical grains of iron-oxide closely scattered throughout a matrix of pale-brown marl which yielded the following characteristic fossils:—*Lima* (*Plagiostoma*) *subrigida* Roem., *Trigonia ingens* Lycett, and a small fragment of *Crioceras*.

Spilsby Sandstone.—Little of this formation came under observation owing to the failure to draw cores; but sediment-samples obtained between the depths of 48 and 128 ft. were mainly composed of fine and coarse quartz sands. The basement-bed was shown in a core, and proved to be 1 ft. thick. It was highly fossiliferous, containing several indigenous shells in the upper two-thirds, while in the bottom layer, 4 in. thick, numerous rolled black phosphatized casts of fossils and phosphatic nodules were embedded in a dark green matrix of fine quartz-sand. These had evidently been derived from the upper portion of the Kimmeridge Clay.

Amongst the indigenous shells several fragments of an ammonite, obtained immediately above the nodule-bed, appear to belong to a species closely comparable with *Craspedites nodiger* (Eichw.).[1] The fragments are mainly of the outermost whorl, and are ornamented by short well spaced somewhat swollen node-like primary ribs; these give rise to three or more faint narrow secondary ribs which pass over the periphery and unite with the primary ribs on the opposite side. One of the fragments of the outer whorl shows the impression of the secondary ribs on the outer area of the earlier whorl, and the ornament thus preserved, the shape of the whorl, and the degree of involution are in complete agreement with a specimen ascribed by Pavlow to *C. nodiger*, presented by him to the Museum of Practical Geology. *Craspedites subditus* Traut. has been recorded by Lamplugh[2] from the Spilsby Sandstone, and a comparable form from Beds D 4-8 of the Speeton section; but *C. nodiger* differs from this species by its greater thickness, and by the smaller number of primary ribs or nodes. The ammonite-fragments are associated with *Belemnites lateralis* Phill. and *Pecten* (*Syncyclonema*) *orbicularis* J. Sow., and their whitish shells contrast markedly with the black phosphatized casts found in the nodule-bed at the base.

Among the black phosphatized ammonite-casts a well-preserved fragment of a Perisphinctid, 5 centimetres in length, was

[1] E. d'Eichwald. Lethæa Rossica (Period Moyenne), 1866. Atlas pl. xxxvi, fig. 3A, not fig. 3B.

[2] 'On the Speeton Series in Yorkshire and Lincolnshire,' *Quart. Journ. Geol. Soc.*, vol. lii, 1896, p. 200.

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obtained. It is ornamented by a number of strong rounded primary ribs which on bifurcation give rise to two secondary ribs of similar size and strength, and in this respect, as well as in the shape of the whorl, the shell exhibits a close relationship to the specimen figured by Michalski[1] as *Perisphinctes panderi* d'Orb. which he regards as a transitional form from *P. dorsoplanus* Mich. An examination of the suture, which is well shown on the Donnington fragment, affords additional evidence of the close affinity to *P. dorsoplanus*. It is nearly identical with the figure of the suture-line of that species given by Michalski.[2] The Donnington shell also shows a close resemblance to the specimen assigned by Pavlow[3] to *Olcostephanus* (*Virgatites*) cf. *panderi* d'Orb., from Bed E at Speeton. The Speeton shell is abraded through rolling, but it shows somewhat deeper interspaces between the ribs. *P. panderi* occurs numerously in the Virgatites Zone in the neighbourhood of Moscow. This zone includes the narrower zones of *Virgatites miatschkoviensis* and *Perisphinctes pallasianus* in Salfeld's zonal scheme[4] for the Kimmeridge Clay of England; and since the higher of these two, the Pallasianus Zone, is separated from the zone of *Craspedites subditus* by at least six separable zones, we must regard the specimen as a derivative from the Kimmeridge Clay, thus confirming the earlier observations that the Spilsby Sandstone rests unconformably on the Kimmeridge Clay.[5]

Kimmeridge Clay.—The highest beds of this formation passed through in the boring were not represented by cores; but at 159 ft. from the surface, or 30 ft. below the local top of the Kimmeridge Clay, several specimens of a finely ribbed *Perisphinctes* occurred. These shells apparently belong to an undescribed species, and they are identical with or closely related to certain similarly ornamented Perisphinctids which characterise the oil-shale horizon in the upper part of the Virgatites Zone at Kimmeridge. They have also been found in certain bituminous shales at Acre House Mine in Lincolnshire and at Speeton. This wide distribution and restricted vertical range renders these shells important as zonal indices, and, assuming the absence of any abnormal condensation of deposits, their occurrence makes it probable that the highest part of the Kimmeridge Clay existing at Donnington falls within the lower part of the Pallasianus Zone or near the summit of the Virgatites Zone.

Judging from such specimens as it was possible to collect at a time when the cores were not fully available it appears that the zonal sequence is complete. Thus at the depth of 199 ft. the occurrence of specimens of *Gravesia* indicates the Gravesia Zone; at 308 ft. shells referable to *Aulacostephanus eudoxus* (d'Orb.)

[1] A. Michalski. 'Die Ammoniten der unteren Wolga-Stufe.' *Mém. Comité Geol. Russ.*, vol. viii, No. 2, 1894, pl. xii, fig. 1.

[2] Op. cit, pl. xi, fig. 3.

[3] Pavlow and Lamplugh. 'Argiles de Speeton et leur équivalents.' Moscou, 1892, pl. v (ii), fig. 5, and p. 115.

[4] H. Salfeld. 'Certain Upper Jurassic Strata of England,' *Quart. Journ. Geol. Soc.*, vol. lxix, 1913, pp. 423-432.

[5] 'The Geology of the Country around Lincoln,' *Mem. Geol. Surv.*, 1888, p. 82.

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were found in association with an apparently new species of *Amoeboceras*, which is closely related to certain forms formerly, though wrongly, referred to *Ammonites kappfi* Opp., from the upper Aulacostephanus Zone of Kimmeridge Bay. Fragments of similar shells were obtained in association with *Exogyra virgula* Defr. in a boring known as Holme No. 1 (unpublished), near King's Lynn, at the depth of about 100 ft.

In addition to the above-mentioned ammonites the following forms were obtained:—

Nodosaria sp.
Lingula ovalis? *J. Sow.*
Orbiculoidea latissima (*J. Sow.*)
Anomia sp.
Corbula sp.
Cyprina sp.
Grammatodon longipunctata (*Blake*)
Grammatodon sp.
Lucina minuscula *Blake*
Ostrea bononiae *Sauvage*
Pecten (Camptonectes) morini *de Lor.*
Protocardia morinica *de Lor.*
Alaria sp.
Fish scales

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APPENDIX IV.

On a Boring for Coal at Winterbourne, Gloucestershire.

By T. C. Cantrill, B.Sc., and B. Smith, M.A.

The northern part of the Bristol Coalfield lying between Cromhall and Mangotsfield takes the form of a syncline with an axis ranging about north-north-east and south-south-west. Its western margin is, however, covered unconformably by the Keuper Marl, under which a part of the Pennant Series and the whole of the Lower Coal Series are hidden from view. With the object of testing the character of these lower divisions of the Coal Measures a boring was commenced in December, 1915, at Winterbourne, 6 miles north-east of Bristol. The results showed that while coals are present, their small number, their poor quality, and their depths are not such as to encourage immediate sinking.

Through the kindness of Mr. R. M. Dillwyn, of Bridgend, Glamorgan, permission was given to the Geological Survey in March, 1918, to visit the borehole and examine the cores. Several marine bands were detected, and numerous fossil plants collected at various depths.

The operations were carried out by Messrs. Vivian's Boring and Exploration Company, Limited, under the management of Mr. Fisher Ray. The total depth attained was 2,338½ ft., most of which was represented by cores.

The Geological Survey Map (Old Series, Sheet 35) shows that the trial was made on the extreme eastern margin of the Keuper Marl, from beneath which the Pennant Grit emerges and extends eastward with a low dip toward the axis of the coalfield. The boring should therefore pass through a few feet of red marl and a considerable thickness of Pennant before reaching the Lower Coal Series. This proved to be the case.

The following is an abstract section of the borehole:—

Boring for Coal on the eastern side of the main road from Bristol to Winterbourne at a point 320 yds. N. of the Bradley Brook Viaduct on the Great Western Railway. New Series one-inch Ordnance Map, Sheet 264 (Bristol); six-inch map, Gloucestershire 68 S.E. Old Series one-inch Geological Map, Sheet 35. Lat. 51° 31′ 5″. Long. 2° 30′ 38″. Height of surface above O.D. about 140 ft.

Boring commenced Dec. 1915, finished Dec. 1917; chiselled to 24 ft. 7 in., continued by shot-boring to 1,575 ft., by diamond-boring to 2,293½ ft., and finished by shot-boring to 2,338½ ft. Diameter of cores, 10½ in. to 2½ in. Dips—at 596 ft., low; at 1,703 ft., 15°; at 2,230 ft., 10°; at 2,254 ft., 5°. Average about 10°.

	Thickness. Ft.	In.	Depth. Ft.	In.
Keuper Marl:—				
Soil	1	0	1	0
Soil and red clay	5	0	6	0
Red clay	5	0	11	0
Coal Measures:—				
Pennant Series:—				
Pennant sandstone, red and grey, with occasional bands of red clay, conglomerate (*e.g.*, at 213 ft.), and films of coal ..	327	10	338	10
Coal, soft	1	8	340	6
Fireclay with ironstone, and shale	25	0	365	6

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	Thickness. Ft.	In.	Depth Ft.	In.
COAL MEASURES—*cont.*				
Pennant Series—cont.				
Pennant sandstone, grey, with occasional bands of shale, conglomerate, fireclay, ironstone and films of coal	535	0	900	6
Lower Coal Series:—				
Grey pennant sandstone, sandy shales (some red and mottled), ironstones and coarse conglomerates. *Marine Band* at 1,090 ft.	192	6	1,093	0
Coal, soft	–	6	1,093	6
Black shales, dark fireclays, and ironstones	11	3	1,104	9
Coal, bastard	–	3	1,105	0
Fireclays and sandy shales (some red and mottled), pennant sandstones, conglomerates (*e.g.*, at 1,290, 1,302 and 1,443 ft.), and ironstones	338	6	1,443	6
Grey shales, ironstone and fireclays; some red and mottled shales. *Marine Band* at 1488-1494 ft.	160	11	1,604	5
Coal, soft	1	1	1,605	6
Grey shales, fireclays and ironstones ...	127	10	1,733	4
Coal 2 ft. 11 in., black shale 1 in., coal 10 in.	3	10	1,737	2
Black and grey Shales, fireclays and sandstone	16	1	1,753	3
Coal	–	10	1,754	1
Black and grey shales, fireclays, ironstones and sandstones	29	9	1,783	10
Coal	–	6	1,784	4
Grey fireclays, shales and ironstones ...	26	8	1,811	0
Coal	–	10	1,811	10
Grey shales, fireclays, sandstones and ironstones	47	10	1,859	8
Coal, soft, 7 in., dark fireclay 3 ft., coal, soft, 2 ft.	5	7	1,865	3
Grey fireclays, shales, sandstones and ironstones	20	6	1,885	9
Coal	–	6	1,886	3
Grey fireclays, shales and sandstones ...	18	1	1,904	4
Coal and black shale mixed (little being coal)	5	0	1,909	4
Grey fireclay	4	2	1,913	6
Coal	1	10	1,915	4
Shales (some red), fireclays and ironstones; hard siliceous sandstones at 2,036 ft. 9 in. and 2045 ft. 3 in. *Marine Band* at 2,000 ft.	133	2	2,048	6
Coal, 1 ft 9 in., fireclay 1 ft., coal 4 in., black shale 3 in, coal 3 in.	3	7	2,052	1
Grey fireclay	2	4	2,054	5
Dark grey shale	3	4	2,057	9
Ironstone	–	9	2,058	6
Dark grey shale	3	0	2,061	6
Coal, soft, 1 ft. 3in., fireclay 7 in., coal, soft, 5 in.	2	3	2,063	9
Fireclays, shales and ironstones	11	3	2,075	0
Coal	–	4	2,075	4
Fireclays, shales and ironstones	16	10	2,092	2
Coal	–	2	2,092	4
Fireclays, shales, ironstones and sandstones	22	11	2,115	3
Coal	–	6	2,115	9
Shales, fireclays and ironstones	50	11	2,166	8
Coal	–	4	2,167	0

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	Thickness. Ft.	In.	Depth. Ft.	In.
COAL MEASURES—*cont.*				
Lower Coal Series—cont.				
Shales, fireclays and ironstones	73	10	2,240	10
Coal, 10 in., black shale and coal mixed, 8 ft., coal 3 ft.	11	10	2,252	8
Shales, fireclays and ironstones	9	10	2,262	6
Coal, inferior, 1 ft. 3 in., black shale and coal mixed, 7 in.	1	10	2,264	4
Shales, fireclays and ironstones, with siliceous sandstones from 2,289 to 2,294 ft. 9 in.	72	8	2,337	0
Loss	1	6	2,338	6

Correcting for a dip of 10°, the total thickness proved is 2,303 ft.

In the above abstract, all the coals are given, though the intermediate beds are summarized. The base of the Pennant Series has been placed at 900 ft. 6 ins., for below this depth pennant-like sandstones, though they are recorded, are subordinate to argillaceous types of sediment. Towards the top the sandstones in the Pennant Series are red, presumably through staining from the Keuper. This reddening extends to a distance of 131 ft. below the base of the Keuper, though red joints are recorded as low as 320 ft. below that base. The red and mottled shales that appear here and there, often at long intervals, in the Lower Coal Series between the depths (from surface) of 912 ft. and 2,121 ft., no doubt owe their colour to contemporaneous causes, and not to Triassic staining.

Specimens of the occasional thin bands of conglomerate in the Pennant Series and the Lower Coal Series were collected for detailed examination. One band, measuring, with interbedded pennant, 5 ft. 6 ins., at 213 ft., consists of subangular and subrounded fragments of vein-quartz and felsites in a sandy matrix. The fragments range up to 15 mm. in diameter.

Three bands from the Lower Coal Series, each a few feet thick, from depths of 1,290, 1,302, and 1,443 ft., closely resemble each other except in the size of the fragments. In the hand-specimens they are characterized by the variety of colour exhibited by the fragments, which are green, pale pink, red, brown, grey, and white.

Dr. Thomas reports the result of his microscopic examination of these conglomerates as follows:—

"E. 11874-11877.—The specimens collected from this boring at 213, 1,290 1,302 and 1,443 ft. from the surface are similar and consist of conglomeratic grits of moderately coarse texture.

"The pebbles and fragments are not completely rounded and in some cases are subangular. They are variously coloured pink, grey, and green, and are for the most part fine-textured rocks. Quartz both transparent and milky occurs as pebbles and appears to be derived in some cases from vein-material and in others from granitic or other igneous rocks. The matrix is moderately coarse grained and sandy and has a buff to grey colour.

"Microscopically the main features that are brought out are the following —Quartzite, sheared and strained, forms a considerable proportion of the pebbles. Other rocks represented are ceratophyric in character and range from devitrified soda rhyolites through microporphyritic ceratophyres to coarser rocks that approach albite granites in composition and texture. Clastic rocks other than quartzites are represented by a relatively small number of fragments of felspathic sandstones and silicified pyroclastic rocks and hornstones.

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"The whole assemblage of pebbles and the general nature of the rock suggests derivation from rocks of considerable antiquity which had been subjected to earth-movement. An ancient Pre-Cambrian ridge similar to that of St. Davids in which albite-bearing rocks are well represented would give rise to conglomerates or arkoses of this character. The probability of the St. Davids area having furnished any of the material is somewhat remote."

Many of the 'grey shales' in the Lower Coal Series would be better described as greenish-grey clunches or mudstones. Some of the shales, fireclays, and clunches contain bands of sphaerosiderite; samples were collected at 2,021 ft. and 2,172 ft., and occurrences noted at about ten other depths. Many of the fireclays look promising from an economic point of view. The numerous ironstone-bands are of the usual coal-measure type—argillaceous carbonate in the form of nodules.

Abundant plant-remains occur in the Lower Coal Series, but are somewhat restricted in their distribution; great thicknesses of greenish-grey clunches proving entirely barren. Sixty samples were collected. Mollusca, which were specially sought for, were found at 6 different depths and 147 specimens were collected. Beside *Carbonicola*, *Schellwienella* and other marine forms have been identified. The marine bands, which are characterized by dark-grey or black smooth mudstone or soapy shale, were found at the depths of 1,090, 1,488-1,494, and 2,000 ft. The apparent association of marine and freshwater shells at the depths of 1,090 ft. and 2,000 ft. is probably due in each case to an alternation of conditions, rather than to an actual mixture of the two faunas. Other bands of similar lithological type were observed at 1,082 ft. and 1,731 ft., but these yielded less definite remains. The identification of the fossils by Mr. John Pringle is as follows:—

PLANTÆ.

	Depths in feet.
Alethopteris lonchitica (*Schloth.*)	2,220.
Linopteris obliqua (*Bunb.*)	1,200, 1,343.
Neuropteris heterophylla *Brongn.*	2,130, 2,220, 2,280.
Pecopteris miltoni (*Artis*)	1,200.
„ sp.	1,200.
Sphenopteris *cf.* elegans *Brongn.*	2,160.
„ *cf.* trifoliata (*Artis*)	2,121, 2,131.
„ sp.	1,200.
Calamites sp.	1,200, 2,231.
Asterophyllites equisetiformis (*Schloth.*)	1,200, 1,258.
„ sp.	1,200.
Sphenophyllum cuneifolium (*Sternb.*)	1,809.
Palaeostachya sp.	1,809.
Lepidophyllum minus *Goode*	1,090.
Cordaites principalis (*Germar*)	1,200, 2,130.
„ sp.	2,191.

ANIMALIA.

MARINE.

	Depths in feet.
Crinoidal remains	2,000
Ambocoelia carbonaria *Hind*	2,000
„ ?	1,090
Cf. Chonetes hardrensis *Phill.*	2,000
Chonetes *cf.* laguessiana *de Kon.*	2,000
Lingula mytiloides *J. Sow.*	1,491, 2,000
Productus sp.	1,490, 2,000

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ANIMALIA—*cont.*

MARINE—*cont.*

	Depths in feet.
Schellwienella *cf.* crenistria (*Phill.*)	1,494
Nucula ?	1,490, 2,000
Nuculana *cf.* attenuata (*Flem.*)	2,000
Schizodus *cf.* antiquus *Hind*	2,000
Raphistoma ?	2,000
Glyphioceras ?	2,000
Orthoceras sp.	2,000
FRESHWATER.	
Anthracomya minima (*Ludwig*)...	About 1,090
„ sp.	1,090
Carbonicola sp. [cf. *Carbonicola robusta* J. Sow.]	1,485
Naiadites *cf.* carinata *J. Sow.*	About 2,000
„ sp.	2,000

The boring shows that there is only one thin coal in the lower 889 ft. of the Pennant Series, and (ignoring seams not exceeding 12 ins. in thickness) only nine in the upper 1,438 ft. of the Lower Coal Series. Some of these coals are soft, or thin, or interbedded or intermixed with shale. But the boring did not penetrate the whole of the Lower Series, and further seams may exist at greater depths. Little is known about this western side of the Gloucestershire coalfield, and the boring does not yield sufficient new data by which a correlation can be made with the measures on the eastern side.

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APPENDIX V.

On a boring at Abbey Mills, Holywell, 1917-18.

By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S.

This boring was made by Mr. A. Timmins, A.M.I.C.E., F.G.S., and we are indebted to him for much of the information concerning it. A shaft was sunk to a depth of 12 ft. within the grounds of the Abbey Mills, at a height of 50 ft. above O.D. and the borehole was made in the bottom of the shaft. The diameter of the hole at the lowest point reached was 6 in. The boring was made in search of water but was not successful. No cores were preserved down to a depth of about 115 ft., and for that part of the record (printed below in italics) we are indebted to Mr. Timmins. For the remainder of the hole a nearly continuous series of cores had been preserved. These were examined by Mr. Pringle, upon whose identification the following account is based, apart from some notes in brackets which relate to specimens sent up to this office by Mr. Timmins during the progress of operations:—

	Thickness. Ft.	In.	Depth. Ft.	In
Superficial Deposits [Glacial]				
Gravel	16	–		
Reddish boulder-clay	32	–		
Yellow and greenish clay	15	–		
Blue silty clay	7	–	70	–
Middle Coal Measures:—				
Grey shales	14	–	84	–
Black shales with thin sandstones and thin coals	3	–	87	–
Grey shales	14	6	101	6
Grey grit	7	–	108	6
Black shale	1	–	109	6
Soft blue shale	2	–	111	6
Lower Coal Measures (Gwespyr Sandstone and Holywell Shales:—				
Grey micaceous laminated sandstones, bedding-planes sharply puckered at 128 ft.	37	6	149	–
Dark-grey sandy shales with thin ribs of sandstone. Plant-fragments numerous	7	–	156	–
Black greasy shales with two hard bands; marine fossils abundant about the depth of 175 ft.	32	–	188	–
White and grey fine-grained sandstones, laminated in places with numerous badly preserved plant-remains at 208 ft.	36	–	224	–
Soft grey sandy shales	14	–	238	–
Dark-grey and grey shaly sandstone with beds of hard sandstone	41	–	279	–
Soft grey sandy shales, with two beds of sandstone	62	6	341	6
Grey shaly sandstone	62	6	404	–
Soft dark-grey sandy shales with *Mariopteris*	21	–	425	–
Fine-grained whitish-grey sandstone	5	–	430	–
Dark-grey sandy shales	12	–	442	–
Fine-grained grey laminated sandstone	20	–	462	–
Soft dark-grey sandy shales	21	–	483	–
Black shales with two dark compact earthy limestones. Goniatites numerous between the depths of 545 ft. and 550 ft.	70	–	553	–
Soft pyritous sandstone with *Stigmaria*	3	–	556	–
Fine-grained white sandstones, micaceous in places, with some dark-grey shaly bands	28	6	584	6

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	Thickness. Ft.	In.	Depth. Ft.	In.
Lower Coal Measures—*cont.*				
Soft dark-grey micaceous sandstones passing below into dark sandy shales with ribs of sandstone	62	3	646	9
Fine-grained whitish-grey laminated sandstones alternating with dark-grey sandy micaceous bands of shale	95	3	742	–
Black and dark-grey shales, becoming hard and splintery below, with several bands of dark compact earthy limestone (cement-stone), varying in thickness from 4 in. to 20 in. Marine shells abundant	198	–	940	–
Black compact earthy limestone (cement-stone), traversed by narrow veins of calcite	5	–	945	–
Fault-rock :—				
Thin-bedded black chert, brecciated and veined with calcite; with galena and specks of copper-pyrites and iron-pyrites	43	–	988	–
Greyish-white crinoidal limestones, silicified in places, with thin layers of black chert in uppermost beds. Limestones coarser in texture near base, and containing numerous grains of quartz; a small lump of galena at 988 ft. (A specimen from 991 ft. consisted of coarsely crystalline brown limestone with films of shale; one from 1,018 ft., of bituminous limestone with black shale filling a vertical fissure; a third from 1,025 ft. contained flakes and fragments of black shale. All three rich in crinoids. Specimens from 1,034 and 1,042 ft. were crinoidal limestones, partly altered into black crinoidal chert)	57	–	1,045	–
Black cherty limestones with a 2 ft. band of grey limestone at 1,057 ft., all veined with calcite. (A specimen from 1,052 ft. consisted of black chert with calcite-joints; one from 1,070 consisted of black chert and black shale similarly veined; another from 1,087 showed a breccia of chert and shale cemented by calcite, and a fourth from 1,090½ ft. consisted of brown bituminous limestone)	46	–	1,091	–
Thin-bedded grey and dark-grey limestones with numerous black shaly partings. (A specimen at 1,092 ft. showed coarsely crystalline limestone enclosing angular fragments of black shale, and another at 1,096 consisted of bedded black shale and limestone, dipping at 28°)	83	–	1,174	–
Grey sandy limestones; *Productus sp.* abundant ...	20	–	1,194	–

From these and the observations made by Mr. Timmins the dip appears to have been from 15° to 29° to a depth of 600 ft., 29° at 735 ft., 40° from 900 ft., 15° to 17° at 998 ft., 28° at 1,096 ft, and 40° at 1,111 ft.

The boring was situated near the margin of an area where the Middle Coal Measures are believed to underlie the Glacial Deposits, and the grey and black shales, 41½ ft. thick, first encountered, may be attributed to that sub-division. Below these the sandstone worked in the Gwespyr Quarries might be expected, and, as a fact, the sandstone 37½ ft. thick was found by Mr. Pringle closely to resemble the rock of the quarries, a peculiar puckering of the bedding-planes being noticeable in both. As a sub-division, however, the Gwespyr Sandstone, southwards from Gwespyr, becomes increasingly difficult to separate from

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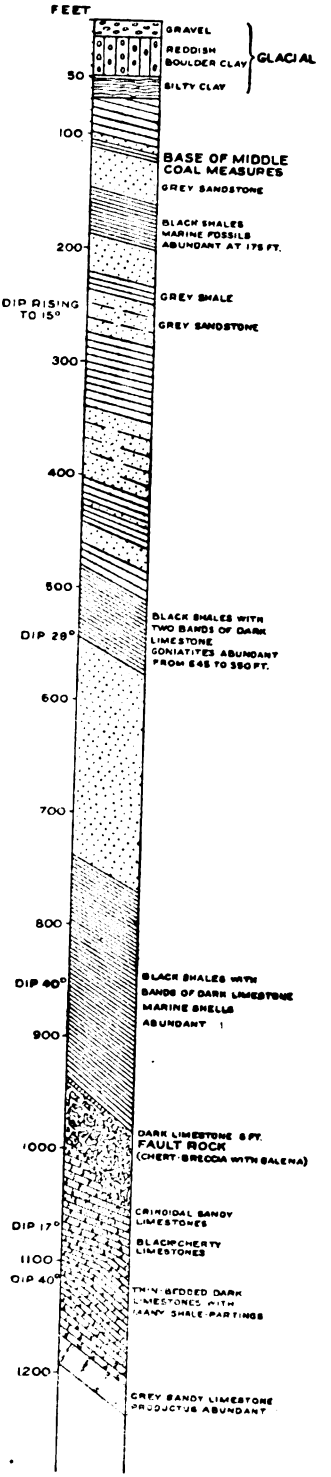
FIG. 3.—SECTION OF THE ABBEY MILLS BOREHOLE, HOLYWELL.



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the underlying Holywell Shales. There is no definite distinction possible into a sandstone- and a shale-group; the two types alternate, and in the borehole fossiliferous shales, as usual black and associated with black argillaceous limestones, occur at the top, the middle and the bottom of the series. Nor is any distinction possible between the fauna of a fossiliferous shale in what has been called the Gwespyr Sandstone and that of a fossiliferous band in the Holywell Shales. The two sub-divisions therefore have been grouped together in the record of the borehole. The length of core assignable to them amounts to 833½ ft., and if correction be made for the dip, the actual thickness may be taken as about 750 ft. It may be noted that light-coloured highly calcareous sandstones occurred at depths of 121 and 139 ft.

That the black limestones at and a little above the depth of 945 ft. correspond to the cement-stones which were once worked in Coed Llwybr-y-bi[1] admits of little doubt. They closely resemble them and occur at the same horizon.

The marine fossils found at depths of 175 ft. and 940 ft. include *Pterinopecten papyraceus* (J. Sow.), *Posidoniella laevis* (Brown), *Glyphioceras reticulatum* (Phill.) and *Glyphioceras sp.*, as determined by Mr. Pringle.

The Chert Beds should have been reached in a short distance below the cement-stones, but it was noticeable that the dip increased rapidly in the lower part of the shales, and that the ground from 945 ft. downwards consisted mainly of fault-rock. The cores broke away in fragments which revolved with the boring tool. One of the lumps thus produced at a depth of 959 ft. may be described as a breccia of black chert and shale with a good deal of galena, specks of copper-pyrites and ribs of calcite. At 970 ft. the boring was reported by Mr. Timmins to be still in fault-rock with galena, and down to 1,087 ft. there were indications of fissuring and of reconstruction. For the last 100 ft. the hole seems to have been clear of the fault and to have traversed some of the higher limestones which crop out on Halkin Mountain. No beds resembling the Black Limestone of Halkin Mountain were recognised, though these form a distinct sub-division at the nearest outcrop. They are impersistent, however, and their absence may be due to this fact, or to their having been cut out by the fault.

As an attempt to obtain water the borehole was a failure, but it has much significance in other respects. The bodies of galena which have been so prolific on Halkin Mountain occur in veins, but tend to follow the intersection of a vein with certain strata. Much ore was got in the Chert Beds, and 'runs' of ore followed, more or less closely, certain beds in the limestone-series, the ore-bodies in a general way dipping eastwards with the strata. The old workings were carried to the bottom of these productive beds under Halkin Mountain, and failure to find ore at greater depths vertically led to a belief that deep mining was useless in Flintshire. The ore-bodies however could not be followed far

[1] 'The Geology of the Neighbourhoods of Flint, Mold and Ruthin,' *Mem. Geol. Survey*, 1890, p. 65.

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down their inclination eastwards, and there remains a possible but unproved lead-field under the cover of Coal Measures in that direction.

The profound influence exercised by shales upon the distribution of the ores, was emphasised in the Memoir descriptive of this district. "The deposition of the ore seems to have been governed not only by the Holywell Shales, but even by the thin bands of shale which occur in the upper part of the limestone; for though in the northern part of the county the ores have generally clustered most thickly under the Holywell Shales, yet in several instances veins, not rich in other parts, have yielded ore immediately below thin bands of shale in the limestone. . . . The influence of the shales on the distribution of the ores seems to have been partly due to their having acted as water-tight blankets, checking the flow of underground water, which must have been eastwards ever since the rocks acquired their present easterly dip. But the precipitation also of the ores of lead and zinc was probably directly due to the giving off of sulphuretted hydrogen during the decomposition of pyrites in the shale."[1] It was clear, therefore, that there existed a possibility that the chert and limestone which underlie the Coal Measures might prove to contain productive veins. The Abbey Mills boring is the first exploration that furnishes evidence on this point.

That the boring passed through a fault is certain, and that the fault belongs to the north-and-south system is probable, for all the faults proved, or inferred to exist, in the neighbourhood of the hole, belong to that system. The existence of specks of copper-pyrites in the fault-rock support the hypothesis, for that ore frequently occurs in the north-and-south cross-courses of Halkin Mountain, but is exceptional in the east-and-west veins.[2] It is open to doubt, however, whether the fault is a downthrow east or west. A fault inferred to exist on surface-evidence, and throwing down to the east, is shown on the Geological Map Flint 6 N.W. It would pass, if it continued, about 100-150 yards west of the borehole, but at this point such evidence as exists is suggestive of a westerly downthrow, and, as a fact, a westerly downthrow of 150 yards has been proved in the Englefield Colliery (about a quarter of a mile farther north) to range towards the same point.

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[1] 'The Geology of the Neighbourhoods of Flint, Mold and Ruthin,' *Mem Geol. Survey*, 1890, pp. 161-2.

[2] *Op cit.*, p 198.

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APPENDIX VI.

On a Boring at Kilnsea, Holderness.

By G. W. Lamplugh, F.R.S.

One-inch Ord. Map (N.S.), Sheet 81.82. One-inch Geological Map (Old Series), Sheet 85.

The boring was made for the War Office in 1916-17 to obtain water, but the results were disappointing. The site is ⅓ mile N.E. of Kilnsea Church, at 25 ft. above O.D., on the neck of land between the Humber and the open sea.

The boring has two features of particular interest: (1) it is the deepest yet made in Holderness; and (2) it is at the most easterly place that a boring could be put down on land north of the Humber. The depth attained was 1,001 ft., and the only other boring in Holderness approaching this depth was one made at Hornsea in 1862-4, which is stated to have gone to 978 ft. in chalk and to have ended in 'black warp or clay,'[1] but the record is unsatisfactory.

The log of the Kilnsea Boring, as supplied to us, is as follows:—

	Thickness, ft.	Depth, ft.
Red marly clay	10	10
Blue „ „	51	61
Silt	2	63
Boulder clay	64	127
Silt	3	130
Chalk	40	170
Soft chalk	468	638
Hard chalk without flints	363	1,001

Brackish water met with up to 800 ft. No water at 900 ft. Brackish water at 1,000 ft., and 3½ gallons per hour in quantity.

A set of specimens was sent for our inspection when the boring was finished, and those from the drift yielded a little further information, as set forth below, but those from the Chalk (at intervals of every 25 ft. or so) had all been pugged into the condition of whiting and showed hardly any difference from top to bottom. A search was made for chips of flint, but none was found, which leads to the conclusion that the Chalk with Flints was not reached, and that the Chalk without Flints may be more than 850 ft. thick in this part of Holderness. At Flamborough Head the Chalk with Flints, the Lower Chalk, and the Red Chalk, together, have a thickness of about 620 ft.,[2] so that if this thickness is continued under Holderness, the whole Chalk formation is likely to be not less than 1,500 ft. thick in the neighbourhood of Spurn Point.

[1] 'The Water Supply of the East Riding of Yorkshire,' *Mem. Geol. Survey*, 1906, p. 106.

[2] For notes on the thickness of the chalk in Yorkshire *see* Lamplugh, *Proc. Yorks. Geol. and Polytech. Soc.* N.S., vol. xiii (1895), p. 75.

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The following are our observations on the specimens:—

From depth of— Ft.	
10	Weathered reddish boulder-clay (resembling 'Hessle-Clay' of cliff-sections).
25	Purple boulder-clay, containing many fragments of chalk.
61	Purple-brown boulder-clay, with crumbs of chalk.
63	" " rather sandy, with a 1½ in. pebble of chalk.
88 and 102 ...	Firm rather sandy darkish purple boulder-clay, with crumbs of chalk; (these and the preceding specimen probably represent the 'Basement Clay' of the coast section).
122	Brownish purple boulder-clay, streaky; (probably some laminated clay pugged among it).
127	Chocolate brown silty clay; no stones.
130	Brown laminated silty sand, with particles of mica and specks of carbonaceous matter.
137	Firm small chalk-rubble ('chalk-wash') mixed with grit; contains a ¼ in. cherty pebble; (like the 'chalk-wash' locally occurring at base of drift on Flamborough Head).
162 to 1,000 ...	Pugged chalk, reduced to powder-paste, smooth and gritless, with here and there a small pellet of dark grey marl (indicating occasional marl partings).

The noteworthy points respecting the drifts, so far as they are represented by the specimens, is the preponderance of boulder-clay; the lack of marked diversity in its composition; the apparent absence of interbedded sand or gravel which is usually abundant in the Holderness cliff-sections; and the presence of fine chalky rubble between the Chalk and the drift. This Chalk-rubble is recorded as part of the Chalk in the log of the boring, but the specimen from the depth of 137 ft. was unmistakably a gritty rubble or 'Chalk-wash,' and not the solid Chalk. As to the thickness of this deposit, the only evidence is that the depth assigned to the specimen is 7 ft. below the supposed top of the 'Chalk,' and that the next specimen, from a depth of 162 ft. is pulverized Chalk evidently representing the solid rock. The thickness of the rubble is therefore more than 7 ft. and less than 32 ft., but no closer approximation is practicable. A similar rubble exposed in the cliff and foreshore at Sewerby, on the south side of Flamborough Head, was found to contain small land-shells, indicating that it had been accumulated on a land-surface.[1] The presence of similar material at Kilnsea at over 100 ft. below sea-level suggests a minimum measure for the elevation of the land above sea level in East Yorkshire prior to the glaciation. The laminated clay and sand between the chalk-rubble and the boulder-clay recalls the presence of similar deposits in the same position in some of the drift-filled valleys of Flamborough Head, *e.g.*, that known as Dane's Dyke. The supposed Interglacial Shelly Gravels of Kelsey Hill and other places in the interior of Holderness appear to have no representative in the section.

[1] Lamplugh. *Proc. Yorks. Geol. and Polytech. Soc.* N.S. vol. xv (1903), pp. 91–5.

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APPENDIX VII.

Further Note on the Boring at Gosmore.

By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S.

In the description of this boring given in the 'Summary of Progress for 1917,' p. 46, reference to a previous boring was accidentally omitted. A boring made at a point about 300 yards N.N.W. of Thistley Farm was described by the late W. Hill in *Proc. Geol. Assoc.*, vol xxiii, 1912, p. 121. It was carried to a depth of 200 ft. and failed to reach the base of the glacial drift. The boring described in the Summary of Progress was situated about 660 yards N.N.W. of Thistley Farm, and was made in 1917. A comparison of the two records shows that the drifts passed through differ in detail; the beds of sand, gravel and boulder-clay are clearly liable to variation. The earlier boring failed to furnish a supply of water.

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MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

1919.

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Geology
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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1919.

I.—INTRODUCTION.

By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S., Director.

The expectation expressed in the Summary for 1918 that the normal work of the Geological Survey might soon be resumed was realised in 1919. A part of the series of Special Reports on the Mineral Resources of Great Britain still awaited completion, and some members of the staff were engaged upon memoirs on iron, lead, zinc, copper, arsenic and antimony, oil and salt in continuation of that series. The work, however, which had been in hand in the early stages of the war was resumed in the Denbighshire and Shropshire district (now more suitably described as the Montgomeryshire and Shropshire district), and the Warwickshire and Staffordshire district. Further work in the London and South-eastern district was postponed for the present.

In the Montgomeryshire and Shropshire district the mapping of the pre-Cambrian rocks of the Shrewsbury neighbourhood has been commenced, and that of the Ordovician has been completed so far as regards the sheets of the one-inch map in hand. A separation of the Ordovician into Caradocian and Ashgillian in accordance with the classification advocated by Prof. Marr has been adopted. The Ashgillian is difficult to distinguish from the overlying Llandovery mudstones by lithological character, but the occurrence of *Pentamerus* in the latter determines their Silurian age. The lower Llandovery beds alone appear to be present, and a gap in the sequence between them and the Tarannon is suspected. The Wenlock and Ludlow are well developed and a precise boundary might be drawn between them on palæontological evidence, but by an expenditure of time which has not been possible.

(945.) Wt. 1489—15/558. 650. 9/20. J. T. & S., L'd. G. 14. Sch. 11.

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The so-called Permian rocks between Wellington and Newport are now relegated to the Keele Beds. They appear to be faulted against the Bunter, but the boundary is obscured. The Glacial deposits are both of local and distant origin. The boulders, which include fragments of marine shells, have been derived partly from northern sources, such as the bed of the Irish Sea and the Lake District, and partly from the neighbouring parts of Wales. Expanses of Late Glacial gravels, at low levels, featureless save for recent river-bluffs, are a characteristic of the neighbourhood, as well as conspicuous developments of the hummocky form so often assumed by Glacial sands and gravels.

In the Warwickshire and Staffordshire district, the small inlier of Silurian rocks, first recognised as such by Mr. Wickham King, has been investigated. For the rest, the work lay principally in the visible coalfield of South Staffordshire and its surroundings. The selection of a line for the base of the Upper Coal Measures required much consideration, and eventually the base of the lowest coarse grit, a distinctive rock above the highest workable coal, was chosen. Good progress was made in mapping the barren upper measures, and the Triassic rocks west of the South Staffordshire Coalfield. The highly important explorations by borings and shafts to the west of the boundary-fault of the coalfield have been kept under continuous observation.

The Glacial deposits completely mask the surface and determine the nature of the soil. They consist of sands and clays with few boulders, all of western origin.

The deep borings that were being made in 1919 to prove the eastern extension of the Nottinghamshire coalfield have been systematically visited, and full particulars have been obtained.

In Scotland also the return of Geologists who had been on active service rendered some field-work possible. The Carboniferous rocks of Ayrshire and Renfrewshire in the neighbourhood of Paisley, Beith and Dunlop were revised by Mr. E. B. Bailey and Mr. J. E. Richey. Most of the district mapped consisted of lavas on the margin of the coalfields. The volcanic rocks are principally basalts of the Dalmeny, Dunsappie and Markle types, but mugearites, trachytes and keratophyres also occur. Old volcanic orifices occupied by masses of trachyte, gabbro and basalt, penetrate the lavas of the plateau; one of them is noteworthy as showing 'ring-structure.' Mr. E. M. Anderson spent a short time on the revision of the Coal Measure areas around Troon and Galston. Mr. Macgregor collected much new information from bores which are being put down in the Douglas coalfield.

In the Highlands, Mr. H. H. Read continued the revision of the Portsoy, Huntly and Insch districts of Banffshire and Aberdeenshire. In that country there is a remarkable series of plutonic igneous rocks ranging from granite to peridotite, exceptionally varied in character and presenting many interesting petrological problems. The exposures of the Highland schists, especially in the coast-section from Buckie to Gamrie, are deserving of careful study.

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Recent Borings for Oil.

The eleven borings that were being made or are in contemplation by Petroleum Development Managers, acting under His Majesty's Petroleum Executive, reached a significant stage by the close of the year. Seven are situated in Derbyshire, two in North Staffordshire and two in Scotland. The results are described on pp. 22-23, 41-43.[1] At present the Hardstoft boring has alone yielded oil in notable quantity. The amount stored at the end of 1919 amounted to 1,900 barrels.

In other borings the strata which yield oil at Hardstoft have proved unproductive.

In addition, oil has been accidentally discovered in a boring at Retford made in search of coal. It was met at a depth of 3,003 ft. in sufficient amount to justify the plugging-up of the hole with a view to conserving the oil for further investigation. Boring operations for oil at Kelham[2] had not been commenced by the end of the year.

II.—FIELD WORK.

(A)—England and Wales.

(1) Montgomeryshire and Shropshire District.

T. C. Cantrill, B.Sc., District Geologist.

B. Smith, M.A.
R. W. Pocock, B.Sc.
W. B. R. King, B.A., O.B.E. } Geologists.

During the past season the mapping of a small area between Llansantffraid-ym-Mechain and Llanfyllin in Montgomeryshire by Mr. Smith and Mr. King has completed the survey of the Oswestry Sheet (137) of the one-inch map.

In the Wem Sheet (138) a belt of country from near Ellesmere eastward to beyond Wem has been mapped by Mr. Pocock. Along the southern border of the sheet and on the northern margin of the Shrewsbury Sheet (152) the work, where suspended at the close of 1915 between Shrewsbury and Wellington, has been taken up by Mr. Cantrill, who has carried the mapping eastward as far as the eastern margins of both sheets.

PRE-CAMBRIAN.

The Uriconian rocks of Wrockwardine are found by Mr. Cantrill to consist of red and purple rhyolites, in places showing fluxion and spherulitic structures. Occasional beds of agglomerate and tuff are present, and some basic intrusions have been noted. The rocks extend under the Glacial drift as far as Admaston, where they are cut through by the Shrewsbury and Wellington railway.

[1] The history and results of the exploration are more fully set out in 'Special Reports on the Mineral Resources of Great Britain,' vol. vii, Mineral Oils, &c. *Mem. Geol. Surv.*, 2nd ed., in the press.

[2] Near the site of the boring described in the 'Summary of Progress for 1917,' *Mem. Geol. Surv.*, 1918, pp. 48–50.

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ORDOVICIAN.

The subdivision of the Bala beds into two stages, viz., Caradocian and Ashgillian, as mentioned in the *Summary* for 1915 (p. 5), has been applied by Mr. King in the Llanfyllin area.

The Caradocian stage consists of sandy mudstones with fine-grained muddy sandstones, one of which, a ripple-marked band somewhere near the middle of the stage, attains a thickness of 10 ft.

The lower portion of the stage is rather poor in organic remains, but in the higher beds fossils became more abundant. These generally consist of brachiopods (*Orthis elegantula* and *O. alternata*), trilobites (*Asaphus*, *Calymene*, and *Trinucleus* of the *concentricus* type) and lamellibranchs.

Near the top of the stage the beds become more calcareous, and lenticular bands of limestone come in, while the arenaceous beds appear to grow ashy. In a few localities where the beds are well exposed (*e.g.*, at Lluest quarry, a mile south of Llanfyllin), thin bands made of fragments of felspars, etc., are to be seen interbedded with the sandy ash-beds and lenticular limestones. These beds contain fossils that resemble those in the sandy mudstones below, although in the quarries at Bwlch-y-cibau certain bands are crowded with large beautifully-preserved specimens of *Strophomena*, which are less abundant in the lower beds.

In the area south and south-east of Llansantffraid-ym-Mechain, mapped by Mr. Smith, the higher part of the Caradocian consists of sandstones and shales with poor cleavage, overlain by black shales with thin bands of limestone.

The sandstone group, where typically developed, consists of tough blue micaceous and laminated sandstones or fine grits, up to 1 ft. in thickness, with interbedded thin shales and sandy mudstones, the softer beds being cleaved. They are characterised in this area by the inclusion of some beds of rather platy fine-grained sandstone of a compact silty nature, traversed by narrowly-spaced strike-joints at right-angles to the bedding. In some of the slightly calcareous beds fossils characteristic of the Caradocian are abundant.

The fine ash and lenticular limestones of the Llanfyllin district pass up into massive grey rather impure limestones. These are well exposed in the Lluest dingle, and appear to be identical with those to be seen in the quarry at Pen-y-garnedd, and which we propose to call the Pen-y-garnedd Limestone. At Bwlch-y-cibau the limestone is reported to have been burnt for lime, and both here and at the quarry near Greenhall these strata contain *Orthis actoniae*.

The phosphate-bed that occurs between the limestone and the overlying graptolitic black shales is not now exposed, although an adit near Greenhall quarry is said to have reached it. At several localities the black shales have yielded graptolites, generally in poor condition except at Pen-y-garnedd quarry, where the section has been opened up and cleared during the war. Some well-preserved specimens collected here have been identified by Miss

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G. L. Elles, D.Sc., F.G.S., who visited the more important sections of the limestone and shales. They[1] prove to be various species of *Orthograptus*. The exact horizon of these shales has, however, not yet been definitely fixed; but from a preliminary study of the graptolites Miss Elles assigns them to the *Diplograptus pristis* zone of Sweden, which is correlated with the highest Caradocian of Britain. The shales, therefore, are a graptolitic facies of a part of the sequence usually represented in this country either by calcareous or arenaceous beds (as at Bala and in Carmarthenshire and Shropshire), or by barren mudstones (as in the Southern Uplands of Scotland).

South and south-east of Llansantffraid the Caradocian beds mapped by Mr. Smith are surmounted by the Pen-y-garnedd black shale group, which has a thickness ranging up to about 100 ft. The shales contain thin bands of crinoidal limestone, the thickest seen measuring no more than a few inches.

In the shales small brachiopods, but no graptolites, have been discovered. They are exposed in a wood (where they are said to have been dug formerly in search of coal) about 400 yards E.S.E. of Vyrnwy Bank Farm, $1\frac{1}{2}$ miles E.N.E. of Llansantffraid. Other exposures occur at Dingle, about half-a-mile farther south. The beds appear to be referable to much the same horizon as the Gwern-y-brain group[2] of the Welshpool District.

The realization on more detailed mapping that the black shales may replace part or nearly the whole of the limestone-group enables us to account for their varying thickness, which was formerly[3] attributed to unconformity between the Caradocian and the Ashgillian stages. This appearance of discordance seems also to have been due at some localities to strike-faulting, which would naturally follow the strike of the soft shales. In no exposure has the Ashgillian been seen to be unconformable to the black shales.

The Ashgillian strata in Mr. King's district near Llanfyllin consist in their lower part of soft green-grey mudstones, with spots and blotches of a darker blue-grey colour. Bedding is not well developed, although, in a few places near the base, nodules, presumably rather more calcareous than the rest of the rocks, are present along bedding-planes. The fossil-contents consist mainly of trilobites and small brachiopods of the species usually met with in the lower part of the Ashgillian in Wales.

The middle and upper parts of the Ashgillian stage tend to become gradually more sandy, although the grains of sand are always extremely fine. Towards the top of the stage, thin siliceous bands come in, and the strata, although retaining their grey-green colour, grow more shaly and sandy, and less like mudstones. The beds are fossiliferous throughout; but it is only in certain bands in the middle and upper portions that fossils occur in any abundance.

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[1] Previously some poor specimens had been identified as *Mesograptus multidens*. 'Summary of Progress for 1915,' p. 5.

[2] A. Wade, 'The Llandovery and Associated Rocks of North-Eastern Montgomeryshire,' *Quart. Journ. Geol. Soc.*, vol. lxvii, 1911, pp. 428–431.

[3] 'Summary of Progress for 1915,' p. 5.

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South of Llansantffraid, in the ground mapped by Mr. Smith, the Ashgillian Beds occupy the centre of a broad synclinorium of folded Caradocian Beds, its central axis lying slightly oblique to the course of the river Vyrnwy.

The strata consist chiefly of greyish-green or blue to brown mudstones, occasionally with sandy lamellæ. Some of the beds are spotted and blotched by little inclusions of a dark-blue tint, recalling the speckled Llandovery beds of the Mynydd-Cricor and Glyn districts in the Llangollen area. In places they are calcareous and contain sandy and calcareous nodules arranged along the dip, with their flat sides at right angles to the bedding. The calcareous nodules occasionally resemble smooth cement-stones, and may form thin beds of limestone. These rocks are richly fossiliferous.

They are overlain by a belt of thin limestones with interbedded ashy shales, well exposed in a quarry 200 yards N.N.W. of Gelli Farm (1 mile S.E. of Llansantffraid), and again in the dingle south-east of Trewylan House, to which position they are thrown southward by a transverse fault. The limestones contain many fine corals. These beds have not been recognised elsewhere within the area covered by the map.

Above the coral limestones the Ashgillian Beds are in the main fossiliferous nodular mudstones, but contain arenaceous matter in the form of thin tough blue laminated sandstones.

SILURIAN.

The detailed mapping of the main mass of Silurian rocks of the Llanfyllin area by Mr. King has led to the discovery of both Llandovery and Tarannon rocks between the Ashgillian and the Wenlock.

The exact base of the Llandovery is usually difficult to determine. This is largely due to the fact that the Ashgillian tends to become more sandy in the higher parts while the lower parts of the Llandovery, though mainly mudstones, contain sandy or siliceous beds. Certain beds presumably near the base of the Llandovery contain bands of calcareous matter. The mudstone of these strata is as a rule rather more blue than that of the Ashgillian. Fossils are scarce, but specimens of *Pentamerus* have been found, which leaves no doubt as to the Silurian age of the beds. Moreover, beds with *P. undatus*, etc., have been found at Pen-y-godor near the River Vyrnwy, in a syncline on the southern margin of the one-inch sheet.

In the extreme south of the sheet, on Allt-gôch, a massive fine-grained grit with basal conglomerate rests on the Ashgillian beds. The grit itself is some 15 ft. thick, and is non-fossiliferous; but the basal conglomerate, which runs up to 2 ft. in thickness, contains numerous fossils. Most of these appear to be small corals, although a few brachiopods also have been found. The majority of the pebbles in the conglomerate consist of vein quartz and fine-grained igneous rocks.

In the Glyn-Ceiriog valley the Glyn Grit was assigned to the Ordovician; but although the grit of Allt-gôch appears to come in at about the same horizon, the field-evidence, as far as it

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goes, tends to place this grit in the Silurian. The matter will probably be settled when the fossil-evidence has been thoroughly worked out. The grit can be traced northwards to near Pant, a distance of about a mile, where it suddenly disappears.

A soft but massive sandstone, 6 to 10 ft. thick, crops out near Rhôs-fawr, on the western edge of the one-inch sheet, and again on Craig-fawr, still farther west, where it has yielded traces of fossils. As these are indefinite, the position of this sandstone in the sequence remains undetermined.

From the fossil-evidence the Lower Llandovery alone seems to be present in this area, and it is probable that there is a non-sequence between the Lower Llandovery and the Tarannon. As the junction between the two can nowhere be clearly seen, the line adopted for the purpose of the map is that which separates pale grey shales and mudstones above from bluer mudstones with various forms of pentamerids—especially *P. undatus*—below.

However, at one locality (Pont Radin in Nant Alan) near the 1-mile stone from Llanfyllin, graptolites have been found which proved to belong to the *Monograptus turriculatus* zone, while at other localities brachiopods have been found.

The Wenlock-Ludlow rocks are mainly of the usual Welsh type of banded mudstone. Graptolites have been found at various horizons, but are abundant in the lower beds alone. These indicate the *Cyrtograptus murchisoni* zone.

The Denbighshire Grits are strongly developed to the west of the one-inch sheet, where three bands can be distinguished. The lowest appears immediately to succeed the *C. murchisoni* zone, while one of the higher grits forms Craig-fâch. On tracing the grits eastwards they rapidly die out, the lowest one alone extending in an attenuated form to Henrhyd-fawr. No sign of the grits is to be seen along the rest of this outcrop, but at the same horizon the beds are usually sandy and sometimes pass into fine-grained banded sandstones.

On the hill above Ty'n-y-celyn (east of Efail-y-cwm in Nant Alan), at about the horizon of the lower grit, a mass of calcareous conglomerate is found in the normal type of Wenlock sediment. The conglomerate consists of irregular lumps of fine muddy limestone, up to several inches in diameter, in a calcareous muddy cement, in which are also found rounded pebbles of hard black mudstone, which weather out on the surface. The conglomerate contains inter-bedded bands of calcareous mudstone, which show contorted bedding. In places graptolites and small brachiopods have been found in the matrix with the dark pebbles.

A similar, though much thinner, bed is seen at Adwy-wynt, to the south-west. Its exact horizon has not been determined, but the pebbles of dark mudstone fill up hollows scoured out of the banded mudstone to a depth of about 3 in. These peculiar beds must have been formed in shallow water that was subject at times to violent current action, which broke up the more or less solidified calcareous mudstone and eroded hollows in the beds that had already been deposited. The pebbles of black mudstone show such perfect rounding and are so unlike any rock

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exposed in the district, that it must be assumed that they were brought from a distance by strong currents near some older land-surface that was then undergoing erosion.

The mudstones below the conglomerate contain here and there a few similar looking dark pebbles scattered with no apparent method through the beds. These pebbles are much more phosphatic than those of the conglomerate and are probably of concretionary origin.

The main mass of the Wenlock-Ludlow series shows no features of particular interest, and the junction between the two stages cannot be traced without laborious fossil-collecting.

The rocks of the Llanfyllin area are thrown into a series of folds with axes ranging approximately east-north-east and west-south-west. This structure is best displayed by the junction of the Caradocian and Ashgillian stages, along which the Caradocian sandstones stand up as hills, while the soft mudstones of the higher stage tend to produce valleys. The anticlines are not symmetrical, however, for their northern limbs display gentle dips, while their southern limbs present vertical or even inverted dips. This indicates overfolding from the north. In similarly folded ground near Bwlch-y-cibau the Ashgillian and even the Lower Llandovery beds are involved.

South of Llansantffraid also, in the ground mapped by Mr. Smith, the Caradocian rocks are similarly folded. Some of the sandstones form sharp arête-like ridges, the two sides representing respectively the dip-slope and the steep scarp. The physiographical features are intimately related to the geological structure, both hills and valleys ranging themselves along synclinal and anticlinal axes. The hills, though of low elevation, possess a striking individuality rarely to be seen in the greater part of the area north of the Tanat valley. The Ashgillian rocks give rise to country of lower relief. The folding is mainly of post-cleavage date.

CARBONIFEROUS.

The 'Permian' rocks shown on the old map (61 N.E.) at Preston-on-the-Weald-Moors, between Wellington and Newport, have been found by Mr. Cantrill to be referable to the Keele Beds of the Upper Coal Measures. They consist of purple and lavender-coloured soft sandstone, yellowish-red sandrock, and salmon-coloured marl. Though their relationships to the surrounding formations are obscured by Glacial drift, it is probable that they are separated from the Bunter of Kinnersley on the north by a fault. Southward they appear to extend under the Drift towards Trench and Hadley, while south-westward they have been proved in a recent boring at Wellington.

TRIAS.

In the area south-west of Llanymynech, evidence has been obtained by Mr. Smith of the former extension or overstep[1] of the Trias across the Carboniferous rocks on to the underlying Ordovician. The evidence takes the form of a purple stain in

[1] 'Summary of Progress for 1915' (1916), p. 8.

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the Ordovician rocks of the hill-margin overlooking the plain of the Vyrnwy and Severn. This stained area, which forms a belt about half a mile wide, extends from New Bridge Vrynwy (about 1 mile S.W. of Llanymynech) for nearly two miles southward. A little hæmatite also occurs here and there in the joints and divisional-planes, and has encouraged prospecting for ore. In this tract the boulder-clay also is occasionally red in tint. Extensions of the stained belt farther southward may be expected.

Near Wem, in the ground mapped by Mr. Pocock, the Keuper Marl forms a feature, possibly due to faulting, trending north-eastwards from Shooter's Hill through Palms Hill and Brockhurst. To the south-east of this line the marl is practically free from drift and there are many small exposures showing red and grey shaly marls alternating with thin sandstones, the general dip being north-westward at about 2°.

At the Drumble the grey marls contain obscure plant-remains, and show traces of copper, while in many exposures the thin sandstones are ripple-marked and contain occasional salt-pseudomorphs.

To the north-west of this area the Keuper Marl is everywhere obscured by drift.

Farther south, in the district examined by Mr. Cantrill, between Shrewsbury, Wellington and Newport, the Bunter rocks, though almost wholly concealed by Glacial deposits, are exposed in the valleys of the Roden and Tern, and also at several points around Kinnersley. The greater part of the area is occupied by the fine-grained soft bright-red and brown sandstones that form the upper part of the Lower Mottled Sandstone, though outliers of the basement-beds of the Pebble Beds form low elevations at Sugdon, Longdon-upon-Tern, Crudgington, and Kinnersley. These outliers have yielded some dull-red and brown sandstones which, though containing small scattered pebbles of quartz, quartzite and igneous rocks, have proved useful for construction work on the local canals, railways and churches.

GLACIAL DEPOSITS.

The Glacial deposits of the Llanfyllin district examined by Mr. King, consist in the main of grey boulder-clay of local origin. Rocks foreign to the district are extremely rare, although on and north of the watershed between the Tanat and the streams draining into the Cain numerous boulders of the felsites of the Llangynog district can be seen. Striæ on rock-surfaces have been found at various points, and in all cases are directed down the valleys, showing that the lower layers of the ice, or perhaps merely the local ice, moved down the existing hollows. This does not preclude the existence of a main ice-sheet that moved transversely over the local ice from the main Welsh icefield towards the Shropshire plain.

Local patches of sand and gravel are found in the valleys, especially where a tributary enters a main valley. These gravels are probably referable to the latest phase of the glaciation, when small glaciers still occupied the valley-bottoms, the gravel being

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washed into the depression between the two ice-streams, and thrown down at the end of the spur dividing them. Pen-y-bryn Terrace at Llanfyllin is built on one of these gravel-spits.

The ground between the Bryngwyn Hills and the alluvium of the River Cain is covered with drumlin-like mounds of boulder-clay, elongated in the direction of the main valley. Near Llanfechain these drumlins apparently block up the old valley of the Brogan Brook which now, after flowing across a wide alluvial plain, cuts across the drumlins at right-angles in a small shallow gorge to join the Cain below Llanfechain. It is probable that the wide alluvial flat marks the site of what was once a small lake.

The Glacial deposits in Mr. Smith's district south of Llansantffraid are similarly of local or western origin. The chief large boulders are of Ordovician sandstone and limestone, and Wenlock grit. The largest specimen found, measuring 6 ft. by 3 ft. by 2 ft. 6 in., consists of fossiliferous sandstone. In an area of about 1½ square miles south and east of the Vyrnwy, and due south of Llansantffraid, the boulder-clay forms a series of twelve or more shapely drumlins rising from 80 to 100 ft. in height. Their longer axes are arranged either west-and-east, or slightly north-of-east and south-of-west.

Some patches of sand and gravel rise as rounded mounds through the Late-Glacial gravels near the main road about a mile south-east of Llansantffraid, and on the higher ground, 400 ft. above sea-level, a prominent tumulus — Hen Domen—has been erected upon a patch of gravel overlying the boulder-clay.

To the south-east of Ellesmere, Mr. Pocock reports that the drift-covered area of sand, gravel and boulder-clay displays a hummocky topography, with meres or peat-mosses in the hollows, as mentioned in the *Summary* for 1914, p. 15.

The sand and gravel forms a distinct belt trending south-eastward from Ellesmere through Cockshutt to Burlton, and is of considerable thickness, a well at Colemere Woods failing to bottom the sand and gravel at a depth of 75 ft.

The hummocky topography becomes less pronounced to the south of Cockshutt, where the belt of sand and gravel flattens out and reaches a lower level as it extends eastward towards Wem.

To the west of this belt of sand the high ground of Kenwick Park, Stanwardine and Petton is formed of boulder-clay, 120 ft. thick at Petton Farm, on which rest patches of coarse gravel and clayey sand, sometimes forming esker-like ridges with a south-easterly trend, as at Whinnett Hill.

The gravel at Kenwick Park, Stanwardine and Petton is coarse and for the most part unbedded. It contains striated blocks of Carboniferous limestone, fragments and pebbles of coal, and much slaty rubble of Welsh origin, including fossiliferous Lower Llandovery and Bala rocks, together with granite boulders and pebbles probably derived from the Lake District. Fragments of shells of marine species now living were noted in the gravel at Stanwardine, and also in the stiff boulder-clay near Weston Common, while at Petton, in the lower part of the pit near the church, fairly complete specimens have been found. A 3-foot

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boulder near Cockshutt has been provisionally identified as from the outer basic portion of the Carrock Fell gabbro.

Boulder-clay occupies most of the ground between English Frankton and Edstaston, north of Wem, with the exception of a belt of gravel following the course of the River Roden. The town of Wem is situated on a considerable spread of this sand and gravel.

Boulder-clay again occupies the ground between this belt and the outcrop of the Keuper at Shooter's Hill, Palms Hill and Brockhurst.

North-west of Wellington and thence towards Newport, Mr. Cantrill finds that boulder-clay overspreads much of the low country lying east of the River Tern, and extends under the Weald Moors around Kinnersley, past Preston, towards Trench. Much of it is red and loamy, and contains fragments of skerry sandstone from the Keuper Marl outcrop to the north, though the numerous pebbles (some of them striated) of Lower Palæozoic rocks, and of Lake District granites, show that some of the constituents are far-travelled. What are apparently the lower parts of this deposit consist of chocolate-coloured stoneless laminated silt, which seems to have been deposited in quiet water, possibly in a Glacial lake. This silt is dug for bricks at two pits near Longdon-upon-Tern.

Succeeding the boulder-clay an irregular sheet of sandy gravel, sand, and loam extends north-eastward through Admaston to Eyton on the Weald Moors, and thence south-eastward towards Trench. The sand is mainly of Triassic derivation and contains pebbles of Bunter and Keuper sandstone, as well as Welsh sandstones, Lake District rocks and occasional flints and shell-fragments. At Burcot, Orleton, Bratton, and Leegomery, the presence of angular pieces derived from the rocks of the Wrekin shows that some of the constituents were carried out on to the lower ground by ice or by water flowing northward.

Above this sheet of gravel and sand a second bed of boulder-clay sets in and forms the picturesque mounds ground of Dothill and Apley Parks near Wellington. Boulders, ranging up to 4 ft. in diameter, of granite and felsite are common throughout the district.

LATE GLACIAL, POST-GLACIAL, AND RECENT.

The Late-Glacial Flood-gravels of the Vyrnwy, described in previous Summaries of Progress[1], were found by Mr. Smith to form broad spreads upon both banks of the river south of Llansantffraid, breaking away in bluffs rising in places 30 or 40 ft. above the stream. To the south-east of a constriction in the valley of the Cain the gravels become mounds and contain numerous kettle-holes occasionally floored by peat, the largest being nearly 30 ft. in depth.

[1] For 1914, p. 17; for 1915, pp. 11–12.

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Small tongues of a Late-Glacial Clay known to underlie the gravel-fan that spreads out on the Shropshire Plain penetrate westward into the hill-country. An irregular tract of this clay, similarly related to the gravels, was mapped also in the drumlin-country south of Llansantffraid, on the east bank of the Vyrnwy. Another flat spread of what must be Late-Glacial as distinct from recent alluvium, occurs west of Deythur. These deposits are of fairly homogeneous, unstratified, and usually yellow, clay with few stones, and appear to owe their origin to mud, derived from the boulder-clay, that slid down the slopes to the lower ground almost immediately after the disappearance of the ice.

Low terraces, covered by brown loam with few stones, have been cut in these Late-Glacial beds at a later period, when the volume of the streams had diminished. The recent alluvium is a brown loam with occasional seams of rather coarser material. In the wider parts of the flood-plain it overlies the gravels that appear to form the river-bed.

Along the valley of the Tern Mr. Cantrill finds that Late-Glacial gravels form terraces between Crudgington and Walcot. They consist of materials derived from the earlier drifts, with an increased proportion of flint-pebbles.

The Weald Moors, which occupy a large low-lying area around Kinnersley (between Wellington and Newport), are covered with a thick deposit of peat and peaty alluvium, in which tree-trunks and roots are occasionally discovered. Popular opinion regards the moors as the site of a lake, but no proof of this theory has been obtained. The sluggish drainage of the district probably gave rise to swamps and later to dense woodlands, which further impeded the waters and ultimately led to a thick growth of peat. That the peat was thicker and more extensive before the Marquis of Stafford's drainage scheme was carried out in 1820, is shown by the stilted condition of the trees still growing on and around the peat-covered ground.

(2) WARWICKSHIRE AND STAFFORDSHIRE DISTRICT.

W. Gibson, D.Sc., District Geologist.
E. E. L. Dixon, B.Sc., A.R.C.S.
R. L. Sherlock, D.Sc., A.R.C.S.
T. H. Whitehead, B.Sc., A.R.C.S.

The surveying of the South Staffordshire Coalfield (sheets 167 and 168) and of the region lying to the west (sheets 139 and 153) was continued.

SILURIAN.

The small inlier of Silurian rocks exposed in the crest of the Netherton Anticline at Saltwells, between Brierley Hill and Netherton, has been mapped by Mr. Whitehead. The succession determined by Messrs. King and Lewis[1] in 1912 corresponds

[1] *Geol. Mag.* for 1912, pp. 437–43, 484–91.

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closely with that established by Miss Elles and Miss Slater[1] at Ludlow, and consists of:—

4. Red Passage Beds, red and purple marls and sandstones.
3. Temeside shales, with bone-beds.
2. Downton Castle Sandstones.
1. Upper Ludlow Shales, with bone-bed at top.

For the purposes of the map, Nos. 3 and 4 have been grouped together. In their paper of 1912, Messrs. King and Lewis described the Red Beds (4) as Old Red Sandstone, largely on the grounds that the 'lingula' fauna was not found by them above the Temeside Shales. Lingula has since been found in the Red Beds, and in a later paper[2] Messrs. King and Lewis give reasons for regarding them as of Downtonian (Ledbury Passage Beds) age, rather than Old Red Sandstone.

The brine well at Saltwells seems to have been sunk into these red beds, but it appears that they here have a covering of Coal Measures, as beds containing traces of plant-remains, and having the appearance of Coal Measures, are exposed in the banks of the Blackbrook, immediately to the north. The outcrop of the red beds seems to be truncated by a fault some two hundred yards north of the Saltwell.

COAL MEASURES.

The mapping of the Upper Coal Measures and Middle (Productive) Coal Measures south of the Bentley Faults has been continued by Mr. Whitehead. The evidence from shaft-sections, and such observations as can be made at the surface, show that the passage from the grey Productive Measures to the red and purple Old Hill (Etruria) Marls is gradual. Red marls and 'gritty' rocks are occasionally recorded at several levels in the Productive Measures; and a grit of distinctly 'Espley' type occurs about 15 ft. above the Brooch Coal in Messrs. Doulton's smaller clay-hole at Saltwells.

Whenever the Upper Sulphur Coal is shown in a section, mention is almost invariably made of 'red ground' and 'mingled ground,' together with 'rock' and 'pebbly rock,' above it. It seems convenient therefore to regard this coal, which when present is always about 300 ft. above the floor of the Thick Coal, as marking the top of the 'Middle Coal Measures,' or grey productive measures. This arrangement, which was that adopted by J. B. Jukes[3], has the advantage of including in the Productive Series all the coal seams that have ever been worked. When the Upper Sulphur Coal is not present, it is usually the case that 'red ground,' red 'marl,' etc., begin to appear in the records of shaft sections at about 300 ft. above the Thick Coal. At Birch-tree Coppice, near Quarry Bank, and at Mushroom Green, there is a marked development of grits and conglomerates, at a level which seems to correspond sufficiently nearly to that at which the

[1] *Quart. Journ. Geol. Soc.*, vol. lxii, 1906, p. 195.
[2] *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xiv, pt. 2, 1917, p. 90.
[3] 'The South Staffordshire Coalfield,' *Mem. Geol. Surv.*, 2nd ed., 1859, pp. 28–31.

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Upper Sulphur Coal commonly occurs, to justify the use of these beds as a base for the Etruria Marls. Similar conglomeratic and gritty beds are strikingly developed about Dixon's Green and Tansley Hill, but here they seem to persist to a higher level. In the absence of such beds at or near the plane of division, it is only possible to indicate vaguely the boundary between the area of the Productive Measures outcrop and that of the Etruria Marls, by the aid of information as to depth of the Thick Coal derived from numerous shaft-sections.

The thickness of the Old Hill Marls is about 300 ft. near Old Hill, and probably less than this near Blackheath and Cakemore. Towards the north they increase to about 350-400 ft. east of Dudley Port Station.

The Halesowen Beds come into the area surveyed near Cakemore and Blackheath. In the Cakemore marl-pit there occur yellowish grits and conglomerates which rest on purple marls, and which have been identified by Mr. Kay[1] as belonging to his 'Witley Group' of the Halesowen Sandstone series. Having regard, however, to the level of the Thick Coal under the marl-pit, where it stands at 149 ft. above sea-level, giving a depth of less than 450 ft., it seems more reasonable to regard these arenaceous beds as 'Espley' rocks in the Etruria Marls. Very similar beds occur in the Etruria Marls near Tividale and Rounds Green. On the higher ground of the golf course, south of Cakemore marl-pit, and at Round Hill Farm, greenish sandstones and conglomerates of the Halesowen series appear, and are thrown by the eastern boundary-fault against the red beds of the Hamstead group about midway between Round Hill Farm and Brand Hall. Similar indications of Halesowen Sandstone appear on the higher portion of the ground enclosed by the munition factory north of Hurst Green, and also at Rowley Regis Station. The brick-pit, about 250 yards south-west of the station, exposes greenish-grey sandstones overlain by grey clays with signs of a thin coal and yielding many blocks of spirorbis limestone. These clays belong to Mr. Kay's Halesowen Coal and Clays group[2], and are thus well above the base of the Halesowen Beds as a whole. It appears probable, therefore, that the Halesowen Beds outcrop may extend sufficiently far north to include the site of the coal-shafts about 300 yards north of the brick-pit and near Rowley Regis Station, though the depth to the Thick Coal in these shafts is stated to be only 606 ft. South of Old Hill, and in most localities farther to the north, Etruria Marls appear at the surface where the Thick Coal is at a depth equal to, or even considerably greater than this. It is, however, not to be expected that a plane of division, based on purely lithological characters, should maintain a constant position with reference to a datum, such as the Thick Coal floor, when traced over even comparatively short distances. This is especially true of a plane intended to separate two such variable groups as the Etruria

[1] *Quart. Journ. Geol. Soc.*, vol. lxix, 1913, p. 441.
[2] *Op. cit.*, p. 443.

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Marls and the Halesowen Beds, the passage from one to the other of which, is, moreover, so gradual.

Hamstead Beds.—On the upcast side of the Eastern Boundary Fault, south of Oldbury, brown-red, soft sandstones appear, with lenticles of coarse limestone-conglomerate, the latter giving rise to conspicuous features south of Langley Green and near Brand Hall. Pebbles of chert and of limestone, chiefly Carboniferous, but including some Silurian,[1] are abundant in these conglomerates. The proportion of limestone-pebbles relative to those of other kinds, appear to increase as the exposures are followed from south to north, and may be as high as 50 per cent. In a gravel-pit near Bristnall Fields, east of the Bristnallhall-road, and also in the lane called George-road, leading to Warley Woods, there occur breccia-beds, with small subangular pebbles, interbedded with soft sandstones and marls. Pending further evidence from the ground to the south-west as to the persistence of these breccia-bands, no attempt has been made to draw precise boundaries for them.

Igneous Rocks.—The dolerite and basalt of the Rowley Hills may be seen intruded into Etruria Marls near St. Giles's Church, Rowley Regis. There it is in the form of small dykes or sills in the marls, some of the sill-like intrusions being only an inch or two in thickness. No perceptible alteration is produced in the marls.

South of Netherton Church, the small exposure of basalt in the canal-section seems to afford evidence that the intrusion was later than the formation of the fault there exposed to view. The basalt has the appearance of running up the scarp face of massive Downton Castle Sandstone, where that rock is truncated by the fault, and does not cross the fault-plane. About 30 yards to the south, however, where the sandstones against the fault are flaggy, the igneous rock crosses the fault and intrudes itself as sills between the flags. Where the basalt is intruded into the red Downtonian sediments in the canal-bank, some metamorphosis of the sediments has taken place.

Faults.—Mining-plans make it clear that the Russell's Hall Fault, along the western flank of the Rowley Hills, is a complex system of fractures occupying a strip of ground from one to two hundred yards broad. It is in fact part of a belt of much faulted ground nearly half a mile broad. South of Dixon's Green the Russell's Hall Fault is stated to have no hade in the Thick Coal, and to vary in the amount and direction of its hade as it is followed upwards. The downthrow here is believed to be 150 ft. to the south-west, and this throw increases towards the south, but the amount, so far as can be ascertained, has not been actually proved, as the fault usually forms the boundary of properties, and is in consequence never crossed by any workings.

The Eastern Boundary Fault is well marked between Cakemore and Warley by the contrast between the grey Halesowen

[1] W. W. King, *Quart. Journ. Geol. Soc.*, vol. lv, 1899, p. 115.

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Beds on the downthrow side and the red Hamstead Beds on the upthrow side. The throw here must be about 1,100 to 1,200 ft. Smaller faults to the west throw the Halesowen Sandstone down to the east. There is, in fact, a belt of faulted ground extending over a considerable distance east of Cakemore and Oldbury. The trial-boring made some years ago between Langley Green and Londonderry was evidently situated in this disturbed belt, as was shown by the faulted condition of many of the beds passed through.

In the district, surveyed by Mr. Dixon, around Bushbury and Hilton Park, on the western margin of the South Staffordshire Coalfield, north of the Bentley faults, the structure is similar to that at Shareshill and Saredon, as described in the Summary of Progress for 1915, pp. 12–13. Barren red Upper Coal Measures, referable to the Keele and Hamstead Beds, occupy much of the surface, and the Bunter Pebble Beds are confined to isolated outliers on the highest ground. As elsewhere in the Midlands, the Hamstead Beds include water-bearing sandstones and breccias or conglomerates, in which subangular yellow and red cherts derived from the Carboniferous Limestone are abundant. Pebbles of Limestone, though more local, also occur. Similar rocks occur around Lilleshall, and are doubtless referable to the Hamstead Group.

TRIAS.

The examination of the Triassic Rocks which separate the South Staffordshire Coalfield from that of Coalbrookdale, has been continued. Great variability in the development of the three sub-divisions of the Bunter is met with. In the Bushbury area, for instance, Mr. Dixon finds that the Bunter commences with the Pebble Beds, the Lower Mottled Sandstone being overlapped or not developed. Farther north, beyond Penkridge, the Upper Mottled Sandstone is also wanting; but in the Newport district to the west, and generally along the margins of the Coalbrookdale Coalfield, all three sub-divisions are represented.

In the Bushbury district the Bunter occurs in the form of outliers resting on high ground composed of Upper Coal Measures. Farther west Bunter Sandstone, succeeded by Keuper Sandstone and Keuper Marls, forms a broad tract running parellel with the Upper Coal Measures. The junction of this main outcrop with the Upper Coal Measures is not seen, but as generally thought, it is probably a fault, though not necessarily one of large magnitude.

In the Newport district, the Lower Mottled Sandstone presents in several places, and through a thickness of several feet, a remarkable development of 'millet seed' sand, the grains being large, uniform in size and nearly spherical.

East of Brewood two deep borings for water are in progress, and the cores have been examined by Dr. Sherlock. The one at Somerford, after passing through Keuper Marl and Keuper

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Sandstone, has proved 200 ft. of non-pebbly Bunter Sandstone. The other, at Slade Heath, shows that the Drift rests on Bunter Sandstone containing a few pebbles.

South of Smethwick, in the area surveyed by Mr. Whitehead, around Warley Abbey, the Bunter consists of lenticles of sandrock and of semi-consolidated pebble-beds. What appears to be an outlier of these beds survives on the high ground at Hilltop, near Bristnall Fields. The Lower Keuper Sandstone in the Newport area is a typical, coarse, conglomeratic, brown rock, easily distinguishable from the Upper Mottled Sandstone. Southwards, towards Boscobel, Dr. Sherlock finds the Keuper Marls passing down into soft, brick-red sandstones, resembling Lower Mottled Sandstone, and farther east, near Corven and Featherstone, Bunter and Keuper Sandstones are difficult to distinguish.

GLACIAL.

In the district round Newport (Salop) mapped by Mr. Dixon, the glacial deposits fall into three groups:—(1) unbedded clayey-drifts; (2) high-level gravels and sands; (3) low-level gravels, sands and laminated loams and clays.

The unbedded drifts, which are of the nature of 'till,' bear no particular relation to the topography. The high-level drifts cover some of the highest parts of the Keuper Marl outcrop east of the Bunter ridge, fringing the Coalbrookdale Coalfield. The third set appears to have been laid down partly in a lake covering the site of Newport, and the ground to the west, and partly by waters escaping from this lake into valleys draining to the east and south as surmised by F. W. Harmer.[1]

A stiff chocolate-clay, with a local development of loose red sands at its base, occupies the low ground in the Shifnal area. Dr. Gibson notes that this clay is of sufficient thickness to prevent much of the rainfall from percolating into the underlying Lower Mottled Sandstone, and that a geological map, on which superficial deposits are omitted, gives no clue to the character of the soil and subsoil. In the Keuper Marl area, round Boscobel, surveyed by Dr. Sherlock, glacial sands and gravels attain a considerable development, and give rise to a light soil of less agricultural value than that formed out of Keuper Marl.

The well-marked features determined by the 'solid' geology of the Cakemore and Warley area are observed by Mr. Whitehead to die away northwards under a blanket of unbedded pebbly drift. Similar material, but with a larger admixture of clay, lies on the watershed at Blackheath, at a height of about 840 ft. West of Rowley Regis, drift is absent, except for a few signs of it, in the form of clay with pebbles, near Mousesweet, near Old Hill, and scattered Bunter pebbles at Quarry Bank. A small patch of pebbly drift lies at a height of 800 ft., north of Turner's Hill, on the Rowley ridge itself.

[1] *Quart. Journ. Geol. Soc.*, vol. lxiii, 1907, p. 478.

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(3) LEAD, ZINC AND COPPER MINES.

The Northumbrian area was examined by Dr. Stanley Smith, the rest of the Pennine Chain by Mr. Carruthers. Throughout this region, the great majority of the productive veins are in Carboniferous Limestone and Yoredale strata, though a few traverse the Millstone Grit also. They are characterised by a comparatively rapid impoverishment in depth, generally because the fissures "pinch out," but occasionally on account of replacement by other minerals. It is rare to find a vein carrying commercial quantities of ore below 100 fms., and it is not surprising to find that after centuries of working, most of the mineral fields, taken as a whole, show signs of exhaustion. There are notable exceptions, however. The famous "flats" of the Boltsburn Mine, in Weardale, discovered 27 years ago, are still in full work. They appear to be metasomatic replacements of the limestone, parallel to, but rarely in contact with, a thin vein, which has presumably acted as a "feeder."

The Alston Moor country continues to be an important producer, especially for zinc-blende, of which considerable reserves exist. Metasomatic 'flats' are found here also.

Most of the Derbyshire mines, once so numerous and so active, closed down many years ago. Millclose Mine, marked by immensely rich chamber-deposits on either side of the lode, is still in active work. The headings are now far under the Yoredale Shales, nearly two miles from the limestone-outcrop. Most of the innumerable veins scattered over the limestone massif in this country are probably exhausted, but if some efficient means could be devised to cope with the heavy underground water, some of the great "rakes," now drowned out, might again produce galena in quantity.

Interesting evidence as to the date of the Derbyshire ore-deposits is provided by the small lead- and copper-working at the Snelston Mine, near Ashbourne. The ores are found in a fault bringing down Keuper Marl against Carboniferous Limestone, so that, here at any rate, the mineralisation seems to be definitely post-Triassic.

The occurrences of galena and blende in the Carboniferous Limestone and Chert series of Flintshire and Denbighshire were examined by Mr. Bernard Smith, with a view to bringing up to date the detailed account given in the Memoirs on the Geology of Flint, Mold and Ruthin (1890) and the Geology of the Coasts adjoining Rhyl, Abergele and Colwyn (1885).

The abandoned mines near Minera, in ground recently surveyed, were also studied.

The chief mines still in work are in the Halkyn District, but others are ready to reopen in both this and the Holywell districts if deep drainage can be secured or labour-conditions permit. In depth the lodes appear to carry a higher proportion of blende than galena. The future development of this region depends upon a successful unwatering of the ground. The old

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Halkyn Tunnel, driven southward as far as the Llyn-y-pandy Lode, about four miles south of Halkyn, at approximately 200 ft. above sea-level, no longer serves the purpose, for most of the mines unwatered have been worked down to, or below, its level. Further work in these mines entails costly pumping.

It is now proposed to carry the Milwr or sea-level tunnel, which has already proved several of the lodes in depth in the Holywell area, southward into the Halkyn district, and extend it eventually into the Llanarmon field. It is hoped that in that area numerous veins, that have yielded richly in the past, may be found to be prolific in the eastern parts of their courses. The southern extremity of this tunnel is now at the northern boundary of the Halkyn Mines District Drainage Area, and about 200 ft. below the old tunnel.

During the closing stages of the war a pumping-scheme, financed by the Government, was commenced at North Hendre Mine, to unwater several bearing lodes below the Halkyn Tunnel level, but this scheme is in abeyance.

Little is being done at the present time in the Minera district, chiefly owing to the fact that the great Minera veins contain blende, but little galena, in depth, and pumping-charges are prohibitive.

In the Minsterley district of Shropshire, again, the future of the mines depends upon deep drainage. Here the ores of lead and zinc occur chiefly in the Mytton Beds overlying the Stiper Stones quartzite and beneath the Hope Shales—all of Arenig age.

The Leigh Adit Level (399 ft. O.D.) has been completed as far as the Milne Shaft in the Hope Valley, and is now being driven southward to cut a large series of veins formerly worked in the old "Gravels" and "Grit" Mines. Should these prove to be rich beneath the old workings a promising future is assured for the Shropshire Mines. For the Bog Mine pumping has been proposed. At the present date the chief product of the district is barytes, got from shallow levels above water-line.

Mr. Smith also examined occurrences of lead- and zinc-ores in the Ordovician and Silurian rocks, near St. Asaph, in Flintshire, Llansannan, in Denbighshire, and Llanrhaiadr and Llangynog in Montgomeryshire. The Pennant Mine, St. Asaph, is alone in operation.

Some scattered occurrences of copper-ore were also investigated in Denbighshire and Shropshire.

The mines for lead, zinc and copper in Cornwall, Devon, Somerset, Shropshire, Cheshire, Carnarvonshire, Merioneth and Anglesey, were visited by Mr. Dewey.

In Cornwall and Devon, the lead- and zinc-ores occur principally in lodes which course north and south and frequently underlie east. They traverse slates and sandstones of pre-Devonian, Devonian and Carboniferous age. Their gangue

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minerals consist of calcite, fluorspar, barytes, quartz and chalybite. Galena and blende often form an intimate complex; but, blende is the principal constituent in some lodes, as at Wheal Sally and Wheal Alfred. In North Cornwall, where the lodes appear in and near flows of lava, galena is the dominant mineral; it is rich in silver and is frequently accompanied by the ores of antimony.

Lodes bearing galena and blende were formerly worked by opencast pits sunk in the Carboniferous Limestone of the Mendips, and calamine and blende were also mined in the Triassic Basal Conglomerate on the flanks of those hills. No mines, however, are now in work and the dumps have been thoroughly worked over.

Ores of copper, lead and cobalt occur, mainly as carbonates, in the Keuper Sandstone and conglomerates of Alderley Edge, Cheshire. In the underground workings the distribution of the ores is seen to be patchy. Percolating waters have impregnated the sandstone with ores in the neighbourhood of faults and the drainage-waters in the mine are coloured a brilliant green by carbonate of copper. Rich impregnations of galena up to 3 ft. in length can be seen in several of the levels. The mineral envelops the grains of sand and even the pebbles of the conglomeratic beds. The normal 'ore' consists of fine-grained sandstone with a cement of green and blue carbonates of copper.

At Grinshill and some other workings near Shrewsbury, copper-ores have been mined in the New Red rocks and appear to be identical in mode of occurrence and of formation to those of Alderley Edge.

Near Llanrwst, in Eastern Carnarvonshire, there is a large group of mines working lead- and zinc-ores, in most cases by day-levels above adit. The country rock is of Lower Palæozoic age and is fissured by two sets of lodes which course either north and south or east and west. These lodes, in many cases, are mineralised 'shatter-belts' and consist of brecciated country-rock cemented together with calcite, galena and blende. There are indications of a succession of minerals in the lodes from east to west. The Aberllyn Lode consists mainly of brown blende in the form of shear lenticles, galena being rare. A little farther to the west galena forms the principal constituent with a calcite gangue, as at Parc Mines; quartz as a gangue then appears at Old Llanrwst Mine, where it forms a remarkable spongy mass of bipyramidal crystals embedding idiomorphic crystals of galena. Almost due north from these mines pyrites becomes an important accessory. At Cae Coch it is the principal ore and has been wrought.

In Anglesey metallic copper is still being obtained regularly from the drainage-waters of the Parys Mountain Mines by precipitation on scrap-iron; but further mining is not at present anticipated. Some auriferous copper-ore is being mined at Rhos-mynach, Anglesey, and from the old gold-mines of Figre

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and Clogau, near Dolgelley. Zinc- and lead-ores are mined at Moelwyn and Bwlch-y-plwm Mines.

In the Lake District (examined by Mr. Eastwood), ores of lead, zinc and copper are found in Lower Palæozoic strata. The veins around Keswick are in the Skiddaw Slates; those of the Greenside and Coniston fields are in the Borrowdale Ashes, while in the Caldbeck Fells, both rock-groups occur, associated with a complex of igneous rocks.

Most of the veins are filled with broken 'country-rock,' cemented with mineral matter. The leading constituents of the gangue are quartz and barytes, the latter, when in bulk, being restricted to the higher parts of certain veins. Some of the so-called 'lead' lodes contain more blende than galena. Although there are numerous exceptions, 'copper' veins usually trend east and west, hading south, while 'lead' and 'zinc' veins range within 45° either way of north and south, and dip to the east. 'Copper' lodes are sometimes shifted by those carrying 'lead,' while the latter are frequently displaced by barren east and west cross-courses.

The chief ores now raised are those of lead and zinc. Over the whole area, as compared with the Pennines, the galena is notably rich in silver. The amount varies greatly, and seems to have some relation to the presence of barytes. In veins where barytes is abundant, as at Force Crag, the silver content is high —over 30 ozs.—while in lodes carrying little or no barytes (Thornthwaite Threlkeld) it is low—about 10 ozs. of silver per ton of pig lead.

The only zinc-ore of commercial importance is blende. When this occurs with barytes the difficulty of separation, almost insuperable in the old days, has now been got over by oil flotation. The Elmore plant at Force Crag gives a clean blende concentrate, while the crushed barytes is re-dressed and sold as 'barytes sand.'

The lead-zinc ore mines now active are Greenside, Thornthwaite, Threlkeld and Force Crag. Brundholme in Glenderaterra Valley has been re-opened, while at Goldscope in Newlands Vale an attempt is being made to locate the intersections of the copper-lode and 'Sealby's lead vein' in the hope of proving an ore-body similar to that of the great lead-bunch of the Goldscope lead-vein.

No copper-ores are being raised at present, though Coniston, Goldscope and Caldbeck Fells were large producers many years ago. The extensive dumps at Coniston, averaging 1½ ozs. of metallic copper per ton, have recently produced a few tons of sheet-copper by an electrolytic process, but work is now suspended during reconstruction. The chief ore is chalcopyrite, which is associated with iron and arsenical pyrites. Secondary malachite and chrysocolla also occur, but not abundantly.

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(4) Borings for oil in Derbyshire and Staffordshire.

From June to October Mr. Bromehead was stationed at Chesterfield and kept the seven Derbyshire borings under continuous observation, examining all samples of the rocks pierced as they were obtained. In Staffordshire, similar work was done by Mr. Eastwood, who was surveying in that district. By October progress in Derbyshire had become so slow, owing to engineering difficulties, that thenceforward occasional visits only were necessary to obtain all the geological information available.

An account of the progress made up to September, 1919, has been inserted in the second edition of the Special Report on the Resources of Mineral Oil, Kimmeridge Oil Shale, etc., now in the press. The depths and the formation reached by December 31st. are given in the following table:—

Well.	Depth. Sept., 1919.	Depth. Dec., 1919.	Formation reached.
	ft.	ft.	
Ridgeway...	2,815 ...	2,996 ...	Carboniferous Limestone.
Renishaw ...	3,650 ...	3,645 ...	Limestone Shales.
Brimington	2,650 ...	2,660 ...	Limestone Shales.
Heath ...	2,897 ...	2,955 ...	Limestone Shale or Millstone Grit.
Hardstoft ...	3,112 ...	3,112 ...	Carboniferous Limestone.
Ironville 2...	3,570 ...	3,570 ...	Carboniferous Limestone.
Ironville 1...	2,430 ...	2,580 ...	Carboniferous Limestone.
Werrington	1,282 (Oct.)	1,920 ...	Pendleside Series.
Apedale ...	1,350 „	1,350 ...	Lower Coal Measures.

The amount of oil obtained at Hardstoft to the end of the year was 1,900 barrels as compared with 849 barrels to October 1st. The large increase is due to a bailing-test having been made early in December. When the level of the oil was kept at a depth of 1,600 ft., the yield was 20 barrels a day, while with a level of 3,000 ft. as much as 35 barrels was obtained.

At Ridgeway a heavy flow of salt water was met with at 2,898 ft. This water apparently came from the Limestone; it had a temperature of about 110° F. and contained some hydrogen sulphide.

The seepages and other evidence for the presence of petroleum in the Lower Carboniferous rocks of Derbyshire, on which, in part, this exploration was based, lead Mr. Bromehead to suggest that it is the lower part of the Limestone Shales, rather than the Limestone that contains the oil. In many parts of the world, California, Mexico and Galicia for example, where petroleum is indigenous to shales, it is found that commercial supplies are only obtained when a suitable reservoir-rock is brought into oblique contact with the shales. When a porous rock cuts across the bedding of the shale, owing either to unconformity or to faulting, the oil passes by capillarity along the laminæ of the shale, which is impervious in a direction at right angles to the bedding, and accumulates in the porous rock. It

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would appear that the conditions in Derbyshire are of this nature. The section at Kelham indicates that the Millstone Grit is faulted against the Limestone Shales.

At Hardstoft an important fault, proved in adjacent collieries, may be estimated to intersect the boring at a depth of rather more than 3,000 ft. This fault may possibly be connected with the disturbance indicated at Kelham. Its effect at Hardstoft would be to bring limestone into oblique contact with shales, and as a fact between the depths of 3,070 ft., where oil was struck, and 3,112 ft. the samples consist of a mixture of shale and limestone. Again, the character of the oil obtained, its light gravity and colour and low sulphur-content, indicate a shale rather than a limestone as the parent rock.

This theory of the origin of the oil and of the conditions requisite for its accumulation account for the success at Kelham and Hardstoft, provides a reason for the failure at Ridgeway and the two Ironville borings, where the structure was regarded on the anticlinal theory as exceptionally favourable, and does not afford much expectation of success at the remaining wells.

(B)—SCOTLAND.

The surveying of the districts which were in hand in 1914 was in part resumed in 1919. The work had been proceeding in two districts in the Highlands, viz.—

(1) West Highland District under the late Dr. C. T. Clough.

(2) North and Central Highland District under Mr. L. W. Hinxman (now retired).

at the same time revision of the coalfields was proceeding in:—

(3) Ayrshire (Kilmarnock District) under Dr. Clough.

(4) Renfrewshire and South Lanarkshire District, under Mr. Hinxman.

No field-work was done in the West Highland District during the year.

(1) North and Central Highland District.

The igneous rocks of Lower Banffshire and North-west Aberdeenshire (Sheets 86 and 96) have been divided by Mr. Read into an Older or largely pre-foliation series and a Younger or post-foliation series.[1] The Younger Series occurs in two great masses—the Huntly Mass, which was described in last year's Summary of Progress[2]; and the Insch Mass.

[1] 'Summary of Progress' for 1918, *Mem. Geol. Survey*, 1919, p. 24, *Geol. Mag.*, 1919, p. 364.

[2] *Loc. cit.*, p. 28.

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The Insch Mass.

The northern part, which alone comes within Sheet 86, extends eastwards from the Old Red Sandstone of the Bogie Valley for 16 miles almost to Old Meldrum; and northwards for about 2 miles into Sheet 86. The direction of elongation of this and of the Huntly Mass, coincides mostly with the strike of the neighbouring metamorphic rocks.

The rock-types found in the northern part of the Insch Mass are olivine-norite, hypersthene-gabbro, quartz-diorite, syenite and granite. Other types—troctolite, probably peridotite, etc.—occur outside Sheet 86; and until these occurrences have been examined, consideration of the relative ages of the different rock-types must be held over. The order given above is likely to be that of relative age, beginning with the oldest.

Olivine-norite.—The main part of the northern portion of the Insch Mass is formed by two rocks, an olivine-norite and a hypersthene-gabbro. These are easily separable in the field and under the microscope, but whether they are two independent intrusions or only phases of one intrusion, is not yet determined. The olivine-norite forms the north-western part of the gabbro of the Insch Mass. In hand-specimen it is a coarse, dark-greyish rock. It weathers to a great depth in spheroidal masses which contain oval nuclei of fresh rock, the final result being a coarse reddish sand and a soil of great fertility. In slice, the rock is seen to consist of labradorite, olivine, hypersthene, augite, biotite, hornblende, magnetite and apatite. The felspar occurs in large fresh crystals. The olivine is abundant in large rounded grains often bordered by pyroxene. The hypersthene forms large prisms or fingered plates with well-marked pleochroism in green to pink tints, and commonly occurs as a border to rounded olivine-masses. The monoclinic pyroxene forms stout prisms, greenish in colour, with well-marked basal striation and is usually much subordinate to the orthorhombic variety. Yellow to deep-brown biotite builds large plates, often associated with iron-oxide masses. Brownish-green hornblende is of secondary origin and borders the pyroxenes. Apatite is abundant in small clear hexagonal prisms. Variations from this main type are formed by differences in the relative amounts of the two varieties of pyroxene. Occasionally the rock approximates to an olivine-labradorite rock, but then it is easily distinguishable from the troctolites of the Huntly Mass.

Hypersthene-gabbro.—This type of gabbro is found in general in the north-eastern part of the Insch Mass. It is finer in grain than the olivine-norite and weathers into rectangular slabs. In slice it is characterised by an equigrained structure and is made up of labradorite in stout crystals, vividly pleochroic hypersthene-prisms, marginally altered to fibrous green hornblende, abundant augite-prisms with a diallage-structure, and rather large irregular clots of magnetite. Variations from the main type are brought about by changes in the relative amounts of the two pyroxenes.

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Quartz-diorite.—This rock covers much ground in the parish of Kennethmont. It is a fine-grained greenish-grey rock composed of plagioclase, quartz, hornblende, biotite and accessories. The felspar varies from oligoclase to andesine and builds well-formed crystals, often zoned. Quartz is interstitial to the felspars and somewhat variable in amount. Hornblende, yellow-green in colour, is associated with the yellow to black biotite in clusters and rude groupings. Kernels of pyroxene have been observed in the hornblende. The accessories are magnetite, sphene and apatite.

Syenite.—A rock meriting the name syenite is found in the Wardhouse district. It is a coarse rock, showing in hand-specimens large pinkish felspars and small patches of hornblende and biotite. It is usually much weathered, yielding a coarse felspathic sandy soil. In slice, the felspars are seen to be microcline and oligoclase; the former occurs in large plates of last crystallisation, the latter forms turbid well shaped crystals. Quartz is rare. The ferro-magnesian constituents consist of biotite in large, ragged, yellow to deep-brown plates, and of a deep-coloured brownish-green hornblende. Magnetite and zircon occur as accessories. Near Wraes, the syenite has altered the olivine-norite into a rock with large plates of black biotite.

Granite.—Intimately associated with the syenite, and probably not separated in time, is a fine-grained pink granite, well seen near Weets in the Wardhouse district. In slice, this rock is composed of plentiful quartz, abundant microcline and a finely striped oligoclase in large plates. Ferro-magnesian minerals are rare and limited to small patches of a dark greenish-brown hornblende. A similar rock occurs in small knobs breaking through the gabbros at Knockenbaird and Jackston.

Dyke Rocks of the Insch Mass.

Lamprophyre.—In the syenite-area about the Shevock Burn thin dykes of a very rotten lamprophyre are found. The pink- and green-speckled rock shows small round pea-like patches of a dirty-white felspar.

Quartz-dolerite.—A forty-foot quartz-dolerite dyke occurs in the olivine-norite at Auchinbradie, north of Insch. It presents well-marked chilled edges against the norite. In slice, it is seen to be composed of quartz, labradorite, augite and iron-oxide in coarse ophitic association. The quartz-dolerite has an east-and-west trend, and on its line, about a mile west of Auchinbradie, there is a small outcrop of a beautifully variolitic basalt. Other quartz-dolerites with a similar trend occur in the slate and knotted schist areas to the north of the Insch Mass at Blackford, Rothienorman, Petty and Minnonie (Fyvie).

Granite.—In the Shevock Burn several small dykes of acid rock are found, characterised by inclusions of numerous small pieces of hornfelsed slate. The acid dykes contain pink garnet and, according to Dr. Mackie of Elgin, orthite.

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Cordierite-Norites of the Insch Mass.

It was shown in last year's 'Summary of Progress'[1] that cordierite-norites, formed by incorporation of sediment in the norite of the Huntly Mass, are widespread. In the Insch Mass, cordierite-norites and associated rocks capable of a similar explanation have been discovered in the Saphook district, west of Old Meldrum. Here the norite of the Insch Mass gives place to a rock which, while preserving proof of its igneous origin, is crowded with ghosts of sedimentary xenoliths in an advanced state of incorporation in the norite-magma. The minerals of this set of contaminated norites are quartz, various plagioclases, cordierite, biotite, garnet, spinel, sillimanite, hypersthene, zircon and magnetite. This mineral assemblage is similar to that already known from the cordierite-norites of the Huntly Mass. The Saphook group of contaminated norites occurs on the margin of the Insch Mass; the contiguous sediments are the gneiss and mica-schists of the Old Meldrum area.

Contact effects of the Insch Mass.

The contact alteration produced by the igneous rocks of the Insch Mass on the slates on its northern border was briefly mentioned in last year's 'Summary.'[2]

The gradual passage from unaltered well-cleaved slate to a massive spotted rock and finally to a true hornfels was there described. Further work has confirmed those observations. The spots of the spotted-rock zone are due to the heaping together of dusty materials in areas of incipient crystallisation of cordierite and andalusite. Nearer the igneous rocks, the spots give place to definite crystals of andalusite and patches of cordierite, accompanied by sillimanite, garnet and the reddish biotite of the cordierite-hornfelses. At the junction with the igneous rocks, granular pyroxene-hornfelses are found, characterised by the occurrence of pyroxene in small rounded granules. Small plates of biotite, scarce brown hornblende-prisms, grains of clear plagioclase and quartz complete the rock. Some of the cordierite-hornfelses are banded with vividly pleochroic grains of hypersthene. Such spotted rocks and hornfelses are demonstrated to be the result of contact action of the Younger Igneous rocks on slate, but at the eastern end of the Insch Mass a series of andalusite and cordierite-bearing rocks of a different type is observed. These andalusite-schists are especially well seen in the Ythan Valley about Fyvie, whence they run southwards into the aureole of the Insch Mass. They have no kind of relation to any of the masses of Younger Igneous rocks exposed at the surface, but, lithologically and structurally, are comparable to the Older Andalusite-Schists already described from other parts of Sheets 86 and 96.[3] Unfortunately, exposures of the Fyvie

[1] 'Summary of Progress for 1918,' *Mem. Geol. Surv.*, 1919, pp. 29, 30.

[2] *Ibid.*, p. 31.

[3] *Ibid.*, pp. 30, 31.

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Older Andalusite-Schists are poor within the aureole of the Insch Mass, but such as do occur point, though somewhat indefinitely, to a superimposed metamorphism.

(2) Revision of Carboniferous areas.

Ayrshire and Renfrewshire.

A considerable area of the 'Clyde Plateau Lavas' of Sir Archibald Geikie's classification[1] has been revised during 1919. Mr. Richey has worked on an anticlinal belt reaching north-east through Beith, separating the Ayrshire from the Renfrewshire Coalfields, and also on exposures connecting Dunlop and Busby. He has found in this region a persistent top group of microporphyritic basalts of Dalmeny type, accompanied by subordinate macroporphyritic flows, as for instance at Busby. Mr. Bailey has taken up the mapping from Lochwinnoch to the Clyde, on the west side of the Renfrew basin, and has followed this top group in strong development until, about three miles north-east of Bridge of Weir, exposures fail. It is in keeping with Mr. Anderson's[2] earlier work in the Cathkin Hills, east of Busby, that the Dalmeny type, so characteristic in Fife and the Lothians of Geikie's "puy" eruptions, should here enter largely into the constitution of the Clyde Plateau.

Beneath this persistent group of Dalmeny basalts the sequence is more variable. In the Beith anticline Mr. Richey has mapped a thick succession of macroporphyritic basalts of Dunsapie and Markle types, with an intercalation of Dalmeny flows exposed at Rowbank Reservoir and again (probably) west of Neilston. Between Lochwinnoch and the Clyde also, Mr. Bailey finds macroporphyritic basalts in this position, but in their downward continuation these basalts are interbedded with conspicuous mugearites.

Finally south-east of the Beith anticline Mr. Richey observes that the Dalmeny group is separated from underlying macroporphyritic basalts by well-characterised local zones as follows—

(*a*) East of Neilston: mugearites with small felspar-phenocrysts.

(*b*) Half way between Neilston and Dunlop: microporphyritic basalts of Jedburgh type replacing (*a*).

(*c*) North of Dunlop: mugearites (distinguishable from (*a*)) and other trachydolerites, along with Jedburgh basalts (the southern continuation of (*b*)). Trachyte-lavas (20059, 20093, 20102, 20192) and keratophyre (20193) also occur, but their field-relations to other groups have not as yet been definitely fixed.

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[1] A. Geikie, 'Ancient Volcanoes of Great Britain,' vol. i, 1897, p. 368.

[2] E. M. Anderson in 'The Geology of the Glasgow District,' *Mem. Geol. Surv.*, 1911, pp. 102–104.

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Great petrological interest attaches to the Dunlop district. The Calciferous Sandstone lavas of East Lothian, long ago described by Dr. Hatch,[1] include a varied assemblage of trachytic lavas, but, except for minor occurrences in Bute,[2] similar lavas have not hitherto been recorded from the Clyde Plateau, though intrusions of the type are well known. Another link between Dunlop and East Lothian is the presence of hornblende trachydolerites (20060, 20101) recalling kulaite[3].

With the lavas just described, Mr. Richey has mapped a number of volcanic plugs. Of these, two may be selected for mention—(1) a large twin plug of trachyte, two miles north-east of Beith, and (2) a ring-dyke of gabbro surrounding and chilled against an intrusive complex of macroporphyritic basalt, a quarter of a mile east of Greenside Farm, half way between Beith and Neilston. The rocks of the Greenside complex show interesting pneumatolytic effects with the production of albite and epidote. The ring-dyke itself is of unusually small dimensions. Its interior diameter varies from about 150 to 220 yards, and its annular breadth some 30–60 more. It seems feasible to suppose that vertical movement of the earlier central plug resulted in a surrounding cavity which was filled by uprising gabbro-magma.

In the district mapped by Mr. Richey, the Calciferous Sandstone sediments, immediately above the lavas, consist essentially of volcanic detritus of various degrees of coarseness and usually red in colour. These red sediments are fairly rich in iron oxide, as a rule in small scattered grains, but sometimes in definitely oolitic bands.

The lavas below the detrital zone have been rotted by contemporaneous subaerial weathering, as in the case of the top lavas of the Millstone Grit[4] in the same neighbourhood described in Summaries of Progress (*Mem. Geol. Surv.*) from 1913 onwards. Unfortunately valuable beds of fireclay do not seem to have resulted, although the decomposition of the lavas has often proceeded so far as to render it difficult to distinguish the product from some fine marly sediment. Pseudo-stratification has been developed through the flattening of particles during the process of decay; and sometimes it is only the recognition of amygdaloidal structure, or the association with less rotted kernels, that betrays the igneous origin of the resultant clay.

A fine section is seen in Yardfoot Burn, two miles north of Beith. Here it is plain that the weathering has been volcanic as well as post-volcanic in date. The tops of successive flows

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[1] F. H. Hatch, 'The Lower Carboniferous and Volcanic Rocks of East Lothian,' *Trans. Roy. Soc. Edin.*, vol. xxxvii, 1892, p. 119. E. B. Bailey in 'The Geology of East Lothian,' *Mem. Geol. Surv.*, 1910, p. 127.

[2] H. J. Seymour in 'The Geology of North Arran, South Bute and Cumbraes,' *Mem. Geol. Surv.*, 1903, p. 176; and W. R. Smellie 'The Igneous Rocks of Bute,' *Trans. Geol. Soc. Glasgow*, vol. xv, pt. III, 1916, p. 353.

[3] E. B. Bailey in 'Geology of East Lothian,' *Mem. Geol. Surv.*, 1910, p. 125.

[4] 'Summary of Progress, 1918,' *Mem. Geol. Surv.*, 1919, p. 22.

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have been rotted by weathering, while the lower portions have been less altered.

East of Barrmill, two miles south-east of Beith, a still more striking demonstration of inter-volcanic weathering is afforded by thick beds of sediment in association with rotted flows some distance down in the lava-sequence. In the Lugton Water, for example, a completely rotted porphyritic basalt is succeeded by perhaps 40 ft. of volcanic detritus with subordinate entomostracan shales, and this is definitely overlain by a series of hard unaltered lavas of the top Jedburgh-Dalmeny groups.

In the part of the ground mapped by Mr. Bailey, the only good section illustrating the phenomena of weathering just described occurs along the course of the Gryfe Water at Bridge of Weir.

Economics.—Beds of oolitic ironstone have been mentioned above by Mr. Richey as occurring in the detrital zone overlying the Calciferous Sandstone lavas. They are exposed at two localities:—

(1) Gunshill Burn, 350 yards S.S.W. of Holehouse Farm, $1\frac{1}{4}$ mile S.S.W. of Dunlop. Thickness perhaps a few feet.

(2) Yardfoot Burn, 350 yards S.W. of Yardfoot Farm, 2 miles N.N.E. of Beith. Thickness, 2 ft. 6 in.

In the hand-specimen the rock consists of ooliths of hæmatite set in a fine-grained buff-coloured ground-mass. The proportion of ooliths to ground mass is about 1:1. The ooliths vary in size from small round grains up to nodules half an inch in diameter. Under the microscope (20027, 20079) they often show concentric growth-bands, where besides hæmatite some foreign matter can be recognised. The ground-mass is composed of detrital material with many quartz-grains, and is relatively poor in iron.

Analyses of material from Yardfoot have been kindly supplied by Mr. J. Gibson, of the Glengarnock Iron Works:—

	Nodules only. per cent.	Sample of Seam. per cent.
Iron	56·64	25·34
Insoluble Residue	9·7 (including 6·9 silica)	48·50

The insoluble groundmass robs the deposit of any present value.

Small concentrations of iron are also met with in connection with the Calciferous Sandstone basalt lavas rotted *in situ*. Specimens were collected from a pocket at the top of a rotted lava-flow in a railway-cutting on the Glasgow and Kilmarnock Joint Railway, $\frac{1}{2}$ mile E. of Barrmill Railway Station. For this Mr. J. Gibson kindly supplies the following analysis:—

	per cent.
Iron	36·14
Insoluble Residue	34·40 (including 19·00 silica)
Sulphur	0·144
Manganese oxide	0·18
Lime	0·25
Loss on ignition	7·70

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In this case again the high percentage of insoluble residue makes the deposit valueless.

Glacial.—Mr. Bailey finds that the merging of the high lava-country south of the Clyde estuary into the lower sedimentary territory farther east is accompanied by interesting glacial characteristics. Between the drift-free high ground and the more or less completely covered low ground there lies, at intermediate elevations, a certain amount of boulder-clay, everywhere disposed, between the Clyde and Bridge of Weir, in the form of isolated drumlins. These drumlins often stretch athwart the scarp-and-hollow featuring of the lavas they surmount. They commonly attain to 50 ft. in thickness. At the same time drumlins are by no means restricted to the intermediate belt; they are characteristically developed in the boulder-clay spread on the lower ground farther east.

Now the driftless nature of the high ground is probably connected with the rapid movement of the ice where it hurried forward, making up in pace for what it lacked in depth. We may take it then that the ice farther east was also moving rapidly, though not so rapidly as to preclude the deposit of boulder-clay. The drumlin form of the boulder-clay, manifest, as it is, in the first appearance of the deposit, favours one of two alternative suggestions. The discontinuous ice-motion, of which the drumlins are a register, may be:—

(1) A feature of a rapidly moving ice-sheet as such, or

(2) A feature of a rapidly moving ice-sheet where motion comes to be checked by increasing depth.

Of these the former seems perhaps more consonant with evidence from other quarters.

It should be remarked that the particular drumlins upon which the above conclusions are based, are not mere variants of crag-and-tail phenomena.

Farther south in the upland district extending to the east of Beith, the original survey demonstrated that the main glaciation came from the north rather than the south. During the present revision Mr. Richey has obtained abundant confirmatory evidence of this, including striated *roches montonnées* moulded by ice from north-east to south-west.

At Lugton, about four miles east of Beith, Prof. Gregory[1] has advanced evidence suggesting glaciation from S.W. to N.E. The glaciated surfaces seen by him have since been removed, but some 20 yards away in the same quarry there is now exposed indisputable evidence of glaciation from N.E. to S.W. The limestone quarried has an irregular top on which rests a bed of fireclay. This top has yielded during glaciation a number of miniature striated *roches montonnées*, of which the orientation is clearly defined.

[1] J. W. Gregory, 'Glaciated Rock Surface at Lugton, North Ayrshire,' *Trans. Geol. Soc. Glasgow*, vol. xiii, pt. 1, 1907, p. 10.

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No additional area was revised during 1919 in the Central Coalfield, except that the igneous rocks described by Mr. Bailey and Mr. Richey to some extent enter into the marginal six-inch sheets on the west side of the coalfield around Paisley and Bridge of Weir. The revision of that coalfield is now completed so far as the coal-bearing strata are concerned, but considerable areas of the non-productive strata around the field require revision in order to complete the one-inch sheets; this is especially the case in South Lanarkshire (one-inch Sheet 23), of which about a half is as yet unrevised. The coalfields adjacent to the Central Coalfield now call for attention. Mr. Dinham has been at work in the district between Stirling and Denny and has paid special attention to the Lower Limestones, which are excellently exposed in the valleys of the Carron and the Bannockburn. Mr. H. H. Read has begun the revision of the Alloa Coalfield, which, occupying a position between the Fife Coalfield and the great Central Coalfield, forms an important connecting link and requires careful study, especially as regards the sequence and correlation of seams.

Douglas Coalfield.

In the Douglas Coalfield in South Lanarkshire which was being revised before the outbreak of war, no additional area has been revised, but the cores of many of the new bores now in progress have been examined by Mr. Macgregor and the correlation of the seams with those of the other coalfields of Lanarkshire and Ayrshire has been considered. Some of Mr. Macgregor's results are embodied in the following report.

During the past year our knowledge of the Carboniferous formation as developed in the important outlier of the Douglas Coalfield has been considerably increased, and more especially in regard to the Carboniferous Limestone Series. It has been possible, for example, to recognise in the Douglas area horizons which are well-known in the Central Coalfield, and to establish a definite correlation of the Coalburn sequence with that found to the north of the broad barrier of Old Red Sandstone rocks which stretches from Lesmahagow to Lanark. The discovery of *Posidonomya corrugata* in the limy shales immediately underlying the Top Macdonald Limestone, renders the correlation of the Macdonald Limestones with the Hosie Group a matter of certainty. Probable representatives of the Under Limestone and of the Basket Shell-bed of the Strathaven district have also been recognised. Attention has naturally been paid chiefly to the Limestone Coal Group, and the most striking feature it displays in this area is its great variation in thickness. In the Coalburn field, on the west side of the basin, it is from 55 to 66 fms. thick and is probably even less than this below the Millstone Grit of the Poneil area, but where it reappears at the surface on the east at Ponfeigh and Rigside it is nearly twice as thick. The increase is distributed throughout the whole sequence and affects barren strata and coals alike. The latter vary in thickness through-

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out the field, but are unquestionably thicker and more numerous on its eastern margin. The sections given in Fig. 1 bring this out clearly and show in addition the correlation of the seams wrought at Coalburn and at Ponfeigh. In establishing the correlation two thin blackband ironstones have proved of significance; the lower of these—above the Nine-foot at Coalburn and above the Kirkroad at Ponfeigh—is the more persistent and was formerly much wrought. These blackbands are sometimes developed merely as a few inches of irony parrot, but can generally be recognised on careful examination. The upper part of the sequence is in some cases interrupted by the occurrence of coarse gritty sandstones which cut out and replace one or more of the coals. So far as is known these are of local occurrence and the phenomenon is probably analogous to the 'wash-outs' found at Bankend and Dalquhandy in the workings of the Nine-foot Coal.

The sequence at Coalburn is similar to that found in the Muirkirk-Glenbuck area, and the names given to the chief coal and limestone horizons are for the most part common to the two fields. At Ponfeigh and Rigside, on the other hand, a local nomenclature is in use (*see* Fig. 1). The marine band that occurs some 7 to 16 fms. above the Top Macdonald (or Top Hosie) Limestone has been noted in many borings and forms a useful index-mark in obscure ground. It consists of 5 or 6 ft. of shelly impure limestone or limy fakes and corresponds to the well-known Johnstone Shell-bed of North Ayrshire and the Central Coalfield. Over the latter it has been traced from Paisley and Glasgow as far north as Denny and as far east as Bathgate and Wilsontown. The 'Black Metals' of the Central Coalfield are represented by the 4 or 5 fms. of black shales (blaes) containing nodules and thin ribs of clayband ironstone which occur between the Six-foot and Nine-foot Coals or, in the Ponfeigh sequence, between the Stony and Robb seams. The only fossils obtained as yet at this horizon are a few specimens of *Lingula* and in this the Douglas area agrees with the Glasgow and North Ayrshire districts, although at many places east of Glasgow—e.g., at Denny, Bathgate, Wilsontown, Carluke, East Kilbride, etc.—a definitely marine band is found in the 'Black Metals.' The associated claybands were formerly wrought to some extent at Bankend and Auchlochan, but are generally poorly developed in the Douglas field; they correspond to the Logan's Bands of Ayrshire, the California and Banton Claybands of Glasgow and Kilsyth respectively, the Hogg Fence Ironstones of Wilsontown and the Maggie Bands of Carluke, and occur upon the same horizon as the High-band and Mid-band Ironstones at Muirkirk. The coal which commonly underlies this series in the Douglas field is the equivalent of the Thirty-inch of Muirkirk and is wrought at Douglas Colliery under the name of the Back Seam; its equivalent in the Central Coalfield is no doubt the Upper Garscadden Blackband or the thin coal which so frequently takes the place of the latter. The Six-foot coal of Coalburn (or its equivalent, the Robb and Fallowhill of Ponfeigh) represents the Lesmahagow Main Gas,

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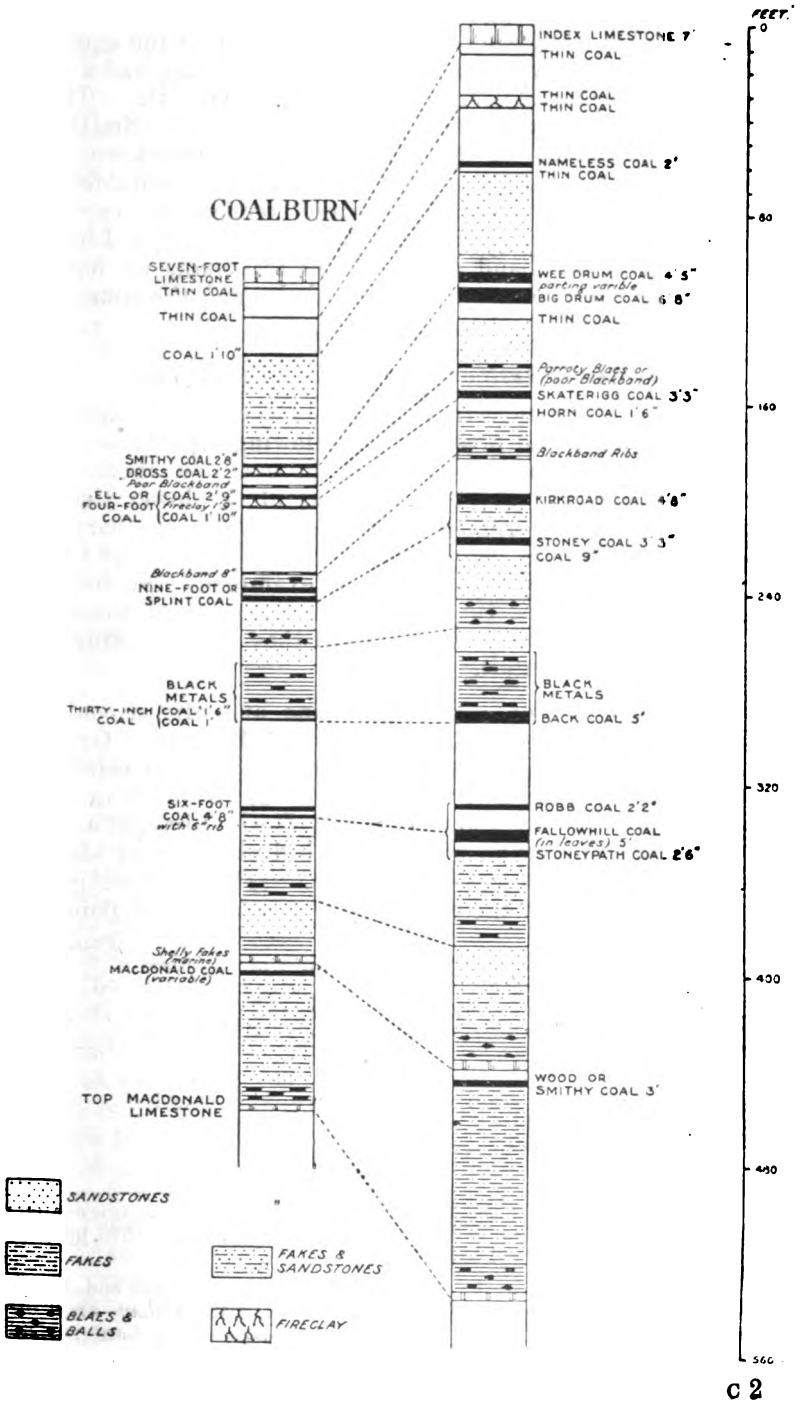
FIG. 1.—COMPARATIVE VERTICAL SECTIONS OF THE DOUGLAS COALFIELD.



C 2

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or Wilsontown Gas, Coal, and at Muirkirk is known as the Catchyburn. Both it and the Nine-foot above it contain ribs of cannel. The latter seam is apparently represented at Ponfeigh by two coals, the Kirkroad and the Stony, and corresponds to the Auchenheath Dross, Carluke Tower, or Wilsontown Main, Coal. The thin blackband above the Nine-foot is the equivalent of the Auchenheath Wee Gas Coal, which generally had a 3 to 5-inch rib of blackband ironstone associated with it. The Ell Coal again is possibly the same as the Auchenheath Smithy, the Lower Carluke Coal, the Fireclay Craw of Wilsontown, or the Jewel of Bathgate, although the absence of any reliable index-horizon in the upper part of the group renders the correlation of the higher seams somewhat doubtful. The Index Limestone has a characteristic band of *Productus latissimus* on top of it, and the same shell may occur scattered through the limestone or immediately below it.

Lower Limestones east of the Kilsyth Hills.

Mr. Dinham has investigated the Lower Limestones of the Bannockburn area and presents the following report:—

In the district between Bannock, in one-inch sheet 31, and Stirling, in one-inch sheet 39, sections of the lower limestones of the Carboniferous Limestone Series, and of that part of the Calciferous Sandstone which overlies the lavas of the Campsie and Kilsyth Hills, have been recently examined. No full report of the development of these strata in this part of the Central Valley appears to be in existence, and they are accordingly now described in some detail.[1]

River Carron section.—There is a fine and almost continuous section of the Limestone Coal and Lower Limestone Groups in the north bank of the Carron above Denny. Some reference to particular beds in the first-mentioned group is made in the last paragraph of this account. The Top Hosie Limestone, at the top of the second group, crops in the bed of the river about 170 yards west of Carronglen Cottage. The following is a generalised section of the strata upstream from that point:—

		Fms.	ft.	in.
Top Hosie.	Dark blue calmy[2] LIMESTONE with pyritised '*Bellerophon*,' *Naticopsis*, and brachiopods, 1 ft.	0	1	0
	Blue blaes with poorly preserved *Orthoceras*, *Sanguinolites costellatus*, and ? *Posidonomya corrugata*, about 4 ft.	0	5	0
	Obscured, about 5 ft.	1	4	0
Second Hosie.	Grey-blue encrinital LIMESTONE with brachiopods, at least 14 in. (visible only at lowest water in mid-stream)	1	5	2
	Obscured, about 2 ft.	2	1	2

[1] Accounts of the Stirling Sill and of some of the sediments in this district are given by Mr. H. W. Monckton in *Quart. Journ. Geol. Soc.*, vol. li, 1895, pp. 480–92, and in *Proc. Geol. Assoc.*, vol. xii, 1892, pp. 242–53.

[2] The following terms are in current use by Scottish miners and borers:—*Blaes*—mudstones, or shales in the geological sense. *Calmy*—argillaceous. *Fakes*—thin-bedded argillaceous sandstone. *Kingle*—a very hard sandstone, often with a limy cement. *Rib*—a thin layer. *Plies*—thin bands.

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		Fms.	ft.	in.
	Hard black sandstone, flaggy at top, about 29 ft.	7	0	2
	Fakes and fireclay, with thin coaly streak, 8 ft. ...	8	2	2
	Kingle with plant-remains, and markings like *Spirophyton* on its upper surface, 2 ft. ...	8	4	2
	Micaceous blaes, with a 3-in. band containing *Aviculopecten, Sanguinolites, Streblopteria*, etc., 1½ ft.	8	5	8
	Fakes and fireclay, 2½ ft.	9	2	2
	Blue blaes with irony ribs and *Orthoceras*, '*Bellerophon*,' and lamellibranchs, 5 ft. ...	10	1	2
? Main Hosie	Grey sandstone, locally ochreous, with encrinites, etc. (probably a decalcified Limestone), 2 ft.	10	3	2
	Obscured, about 5 ft.	11	2	2
	Sandstone and fakes, about 22 ft.	15	0	2
	Dark-blue blaes, faky at top, (under water) ? barren, about 12 ft.	17	0	2
Carron Kingle	Blue limy kingle, weathering like a limestone, with fish-teeth and ? entomostraca; no marine fossils, about 2 ft. 4 in.	17	2	6
	Fakes with sandstone-ribs, passing down into fakes, about 35½ ft.	23	2	0
	Light-blue faky blaes, with white worm-casts, a few marine fossils at the top, 6 ft.	24	2	0
	do. with pyritous pellets and rare encrinites, 26 ft.	28	4	0
	Hard blue flaggy fakes, 2 ft.	29	0	0
	Light-blue faky blaes, with pyritous pellets, and irregular rusty pyritous nodules increasing in size and number towards the base. Encrinites common at the very bottom, 20 ft.	32	2	0
Fankerton Limestone	Limestone with indistinct encrinites, grey and greenish, 2 ft.	32	4	0
	Hardened grey blaes, about 1 ft....	32	5	0
	Limestone, grey and blue, 2 ft. 6 in.	33	1	6
	White crystalline hardened sandstone, about 10 ft.	34	5	6
	Inaccessible, about 6 ft.	35	5	6
	Top of big dolerite-sill	–	–	–

The last-mentioned strata are marmorised and otherwise intensely altered by the underlying intrusion. This sill, which 1½ miles to the north-east is known to be at least 280 ft. thick, continues upstream in the sides of the river until it meets the Campsie Fault, or its continuation, about 150 yards east of a sharp bend below Garvald Mills. There it is thrown altogether above the low right bank, but appears at the very top of the steep left bank, where isolated exposures of ashy sandstones and shales may be seen between it and the Calciferous lavas beneath.

Bannock Burn section.—The strata described in the generalised table which follows, crop out in the valley of the Bannock Burn, 4 to 5 miles S.S.W. of Stirling and about 4 miles N.W. of the Carron section. The greater part is exposed in the bank and bed of the stream about a mile S.W. of the North Third Reservoir of the Grangemouth Water Works; the highest beds, however, are seen only in the (south) Sauchie Craigs east of the reservoir, being cut out at the other exposures by the descending base of the sill which forms the Craigs. This intrusion, like that of the bottom of the Carron section, is a continuation of the Stirling Castle and Abbey Craig Sill.

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		Fms.	ft.	in.
Bottom of dolerite-sill		–	–	–
	Pale-blue blaes, altered near the sill, with numerous pyritous pellets; larger irregular pyritous nodules near the base; occasional encrinites at the bottom, up to 26 ft....	4	2	0
BANNOCK "A" & "B" LIMESTONES.	Blue partly decomposed encrinital LIMESTONE, 2 ft. 6. in	4	4	6
	Barren blue blaes, 1 ft. Obscured strata, 1 ft....	5	0	6
	Blue LIMESTONE with mottled fracture; irregular 'ooliths,' up to more than an inch in diameter, show on the weathered surface. No marine fossils seen. 1 ft. 7 in.	5	2	1
	? Sandy marl, or decomposed dolerite ? 2 ft. 6 in.	5	4	7
	Greenish baked nodular fireclay ?; locally fakes with some blaes, 5 ft. 8 in.	6	4	3
	Sandstone (locally a ganister) and fakes 4½ ft. ...	7	2	9
	Blue crumbly blaes, apparently barren, 6 ft. ...	8	2	9
	Sandstone-posts and ribs, with fakes, 9 ft. ...	9	5	9
	Blue blaes with traces of plants, 1 ft. 6 in. ...	10	1	3
	Black platy blaes, with athyrids, productids, *Lingula*, and a lamellibranch, 4 in.	10	1	7
BANNOCK "C" LIMESTONE	Hard blue encrinital LIMESTONE decalcified, with abundant marine fossils at top and bottom, 3 ft. 5 in.	10	5	0
	Bright COAL 5 in., on soft fireclay 5 in.	10	5	10
	Rubbly sandstone, and sandstone fakes, 19 ft. ...	14	0	10
BANNOCK "D" LIMESTONE	(Obscured by old workings, which extend along the whole length of the sections, 16 to 20 ft.)	17	0	10
	Blaes with small crystals of gypsum, 2 ft.. ...	17	2	10
	Blaes with regular pyritous ribs, 3 ft.	17	5	10
	Blaes with gypsum, 1 ft. 2 in.	18	1	0
	Papery blaes with strongly curved bedding, 1 ft....	18	2	0
	Blaes with lenticles of clayband ironstone; entomostraca and fish-teeth at base, 1 ft. 8 in.	18	3	8
	Blaes with 3 in. limy clayband and occasional marine fossils, 1 ft. 9 in....	18	5	5
BANNOCK "E" LIMESTONE	White and yellow LIMESTONE:—nodular with large encrinites, and coaly films at top, 2½ ft.; more nodular, with lamellibranchs, gastropods, *Fenestella*, rod-like bryozoa and a doubtful coral, 2 ft.; faky and nodular, 1 ft. Total 5½ ft.	19	4	11
	Blaes and limestone-bands, with brachiopods, 2 ft.	20	0	11
BANNOCK "F" LIMESTONE	Grey slabby LIMESTONE, composed of harder and softer bands. Top 3 in. locally slightly nodular, remainder very fossiliferous (encrinites, *Archaeocidaris*, *Tabulipora scotica*, and brachiopods. No corals noticed), 2 ft. 2 in.	20	3	1
	Blue micaceous blaes with a 6-in. clayband. *Lingula* and fish-remains locally, 2 ft. 2 in. ...	20	5	3
	Ashy marl or mudstone (locally blaes with plant remains), 1½ to 3 ft.	21	1	6
	Ashy sandstone often quite green, hard or soft, 3 to 6 ft.	21	5	6
	Ashy fakes and blaes (locally a coarse detrital ash), with ashy sandstone-ribs at bottom, 7 to 9 ft.	23	1	6
	Blue thin blaes, apparently barren; ribs of fakes and ? pyritous ironstone in bottom half. 13½ ft.	25	3	0

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		Fms.	ft.	in.
Bannock "G" Limestone	Limestone: faky, with exceedingly abundant fossils, including giganteid *Productus*, *Lithostrotion* and a clisiophyllid coral, 3 in.; compact, locally lenticular, with brachiopods, 6 in.; faky, with abundant fossils (encrinites, brachiopods, large productids lying on their ventral valve, '*Euomphalus*,' lamellibranchs, and a zaphrentid coral), 9 in. Total, 1 ft. 6 in. ...	25	4	6
	Blue blaes, partly ashy; at base a thin layer of ? mother-of-coal with cone-in-cone structure, 2 ft.	26	0	6
	French-grey mudstone or ashy marl, 1½ to 3 ft. ...	26	3	0
	Line of discordance.			
	Bedded variegated detrital 'ash,' with nodules of hard chocolate 'marl'; the beds are clearly truncated by the overlying stratum, about 20 ft.	29	5	0
Lavas of the Kilsyth Hills		–	–	–

The Bannock "D" Limestone must be the "Murrayshall Limestone" formerly wrought at Cambusbarron, 1½ miles W. of Stirling, at Murrayshall, 2 miles S.W. of Stirling, and at Craigend and Touchadam, north of the Reservoir. No section of this seam or of the adjacent strata is now exposed, but according to a century-old record[1] the limestone at Murrayshall was a bluish-black seam 6 ft. thick, with "entrochi" (encrinites) and specks of pyrites, lying in the middle of not less than 35 ft. of dark blaes, partly limy at the bottom. A 3-ft. limestone, 42 ft. above the main seam, rested on 4 ft. of blaes mixed with coal, and thus appears to correspond to "C," the only limestone beneath which a coal has been noticed.

Correlations.—Comparison shows that the above sections cannot be matched with each other, except that the Fankerton Limestone of the Carron resembles the Bannock "A" and "B" Limestones taken together. The intense alteration produced by the intrusion prevents a detailed comparison of the beds, but in each case we have two limestone-seams separated by a foot or so of blaes, lying above more or less sandy strata and beneath several fathoms of blaes which, alike in thickness and in the lithological peculiarities described, differs from any other beds of blaes in the sequence at either place. It is accordingly natural to consider these limestones as equivalent, and this identification leads to consistent results.

In correlating these exposures with the sections at Campsie and Kilsyth, there can be no doubt that the two highest Carron Limestones are the Top Hosie and the Second (or Mid) Hosie[2]. The decalcified limestone in the Carron may be the Main Hosie of the Hurlet District, formerly seen (now quarried away), also in the Burniebrae Burn ("Shields Burn"), Campsie, east of Shields steading, at a horizon about 4 fms. below the Second Hosie. The thick blaes above the Fankerton Limestone resembles that

[1] Lt.-Col. Imrie, *Mem. Wernerian Soc.*, vol. ii (1818), pp. 28, 34, 50, and plate.

[2] Together, the 'Hosie Limestone' (in 2 beds) of Macnair and Conacher, *Trans. Geol. Soc. Glasgow*, xv, part i, (1912–13), pp. 43 and 48, and the Bellerophon, or Hosie, Limestone of 'The Geology of the Glasgow District,' *Mem. Geol. Surv.*, 1911, p. 24.

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which overlies the Blackhall[1] at Corrie and in the lower part o the Burniebrae Burn. As Mr. Carruthers points out, the non marine, "oolitic," nature of the Bannock "B" Limestone i exactly comparable to that of the lower part of the Blackhal Limestone[2], an observation which confirms the conclusion already reached as to the identity of the Fankerton with the Bannock "A" and "B" Limestones. Limestone "C" will then represent the sandy encrinital limestone of Campsie[3], and "D" will be the Hurlet, so that the prevailing identification of the latter with the Murrayshall Limestone remains unchanged. Certain resemblances between the remaining Bannock Limestones and the Corrie section at once suggest themselves; whether the differences from both Corrie and Touchadam (*see below*) are due to lateral variation, to local unconformity, or to both causes combined has yet to be investigated, but the following remarks, extracted from a report by Dr. G. W. Lee on the fossils recently collected from the Bannock section, must be taken into consideration in any correlation.

(1) Blaes below Limestone "D."—These beds contain abundant *Sanguinolites costellatus*, with *Myalina verneuili*, *Euphemus urei*, and a goniatite—all members of the "Abden Fauna," below the Hurlet Limestone.

(2) Limestone "E."—This bed also contains *Productus pugilis* in abundance, *Productus youngianus*, and bands of Bryozoa (*Rhabdomeson*). These faunal characteristics are strongly marked in the White Coral Limestone (to the exclusion of other horizons) at Corrieburn, a seam which the Bannock "E" Limestone closely resembles also in general aspect. All the palæontological and lithological evidence points to the equivalence of these two limestones.

(3) Limestone "F."—There is nothing distinctive in the fauna of this limestone.

(4) Limestone "G."—This is characterised by the abundance of giganteid *Producti*, which, with single and compound corals (*Syringopora*, *Lithostrotion*, *Diphyphyllum*) and other fossils, constitute an assemblage quite typical of the Hollybush limestone fauna, as represented in the Survey collections from the Hollybush district. There is nothing like it in the Corrieburn section.

One result of the above comparisons is that, the Fankerton Limestone being no longer regarded as the Hurlet, the consequent absence of the true Hurlet and of the lower seams from the Carron Section is to be ascribed to faulting, as already mentioned, probably combined with a descent of the sill, on the

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[1] Blackhall Limestone, Glasgow *Memoir*, pp. 22–24; Baldow Limestone of Macnair and Conacher, *loc. cit.*, p. 46; Black Limestone or 'Hosie Limestone' (of Campsie) in Glasgow *Memoir*, p. 23; in John Young, *Trans. Geol. Soc. Glasgow*, i, 1860, p. 27, and do., 3rd ed, 1894, p. 42; in J. Neilson, *ibid.*, xiv, pt. iii, 1911–12, p. 327 footnote, pp. 328–333; etc.

[2] Macnair and Conacher, *loc. cit.* pp. 46 and 49 ('q'), Glasgow *Memoir*, pp. 23 and 24.

[3] Exposed in Cowies Glen (part of the 'Shields Burn'), *see* Glasgow *Memoir*, p. 23; also in the Baldow Glen, etc. This is the 'Shields Bed' of Macnair and Conacher, *loc. cit.*, pp. 45 and 47. It does not yet appear to have been recorded from Corrie.

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upstream side of the fault, to a lower stratigraphical horizon. The latter phenomenon is suggested by a bore through the sill near Quarter, which reached the lavas without any record of limestones or of more than a few feet of normal clastic sediment.

The Touchadam Section.—Farther down the Bannock Burn, ¾ mile below the Reservoir, in the stream at Touchadam Quarry, other sections of lower limestones are exposed in a small syncline. They show such differences from those higher up the Burn that they cannot yet be satisfactorily correlated. The Murrayshall Limestone has been taken out both at the quarry and beneath the crags on the opposite side of the stream where, near the old level, and about 5 ft. below the big sill, a 38-in. seam with abundant *Lithostrotion* rests on a thin ashy bed (? white trap) above 18 ft. of sandstone overlying 12 ft. of barren blaes. This appears to be the Bannock "C" Limestone. Below the Murrayshall Limestone, of which numerous fragments remain in a waste-heap in the quarry, the following sequence can be made out:—

		Fms.	ft.	in.
Murrayshall Limestone	... ...	–	–	–
	? Gap., 0 to about 19 ft.			
	Blaes with *Lingula* and entomostraca, 6½ ft. ...	1	0	6
	Black blaes with fireclay and thin ribs, uneven bedding, 11 in.	1	1	5
	Blaes with *Lingula* and a small lamellibranch, 1 ft. 2 in.	1	2	7
	Fireclay and blaes, 9 in.	1	3	4
	Slaty blaes with *Orthoceras*, goniatites, *Euphemus*, *Sanguinolites costellatus* and entomostraca, 1 ft. 4 in.	1	4	8
	Softer blaes with similar fossils: ironstone-ribs with entomostraca near bottom, 3 ft.	2	1	8
	Blaes with *Lingula*, entomostraca, and two crystalline LIMESTONE ribs, 2 ft. 4 in.	2	4	0
	Pale variegated marls and ashy mudstones with limy nodules, 27 ft.	7	1	0
	Blaes with *Lingula*, 1 ft. 10 in.	7	2	10
GONIATITE-LINGULA LIMESTONE	Slabby LIMESTONE and limy blaes with abundant goniatites and *Lingula*; *Orthoceras gesneri*,[1] lamellibranchs, and fragments of brachiopods. Two ribs of encrinital limestone below the middle, 4 ft. 2 in.	8	1	0
	Blaes with gypsum-efflorescence, pyritous rib near base, 7½ ft.	9	2	6
	Pale marl or ashy mudstone, 9 ft.	10	5	6
	Obscured, about 10 ft.	12	3	6
	Blaes and faky blaes, more or less ashy, about 13 ft.	14	4	6
PRODUCTUS LIMESTONE	LIMESTONE and limy blaes with abundant large *Productus*, about 3 ft.	15	1	6
	Pale ashy blaes, up to 2 ft.	15	3	0
	Bedded chocolate and green 'ash' and marls, ? 30 ft.	20	3	0
Lavas	... ...	–	–	–

[1] A rare fossil recorded previously in Scotland at South Cobbinshaw (from the Raeburn, formerly Mungle, Shell Bed. *See* 'Oil Shales of the Lothians,' *Mem. Geol. Surv.*, 1912, p. 94), and at Craigenglen; also from the Upper Limestone Group.

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The width of the syncline measured between the two crops o the Productus Limestone, is about 150 yards. It is traversed by several small faults, one of which, with a gentle hade and a southerly downthrow of 10 ft., complicates the cliff-section in the left bank, and repeats the crop of the Goniatite-Lingula Limestone in the stream on the southern limb of the fold.

The continuous line of quarries from Touchadam right up to the higher part of the Bannock Burn must surely be in the same seam, viz., the Murrayshall Limestone. If further the Productus Limestone corresponds to "G," the Goniatite-Lingula Limestone to "F," and "E" be represented by part of the 27 ft. of variegated marls with limy nodules, as Mr. Tait suggests, we have then an example of lateral variation which well illustrates the difficulties of correlation among the lower Carboniferous limestones.

Dr. Lee reports that the Goniatite-Lingula Limestone contains a rich assemblage, not represented in the Corrieburn section, which has many points in common with the Basket Shell Bed exposed at Cot Castle near Strathaven. Among these are the abundance of goniatites (including ?*Dimorphoceras*), *Orthoceras*, and brachiopods, and the presence of several kinds of lamellibranchs (including *Cypricardella rectangularis*).

Other exposures.—At Old Sauchie, 1½ miles E. of the Reservoir, the Bannock section is seen again, from the blaes above Limestone "A" to the coal beneath "C." One mile W.S.W. of this point, a disturbed section of quarried limestones is seen in a "window" through the dolerite, on the north side of an east-and-west fault which runs along the Auchenbowie Burn. Immediately south of this fault sandstone, and some blaes with marine lamellibranchs, are seen below the sill; but no limestones are exposed, nor are there any lines of old workings to the southward, and it seems probable that, between the Auchenbowie fault and the point where the Campsie Fault crosses the Carron, the dolerite occupies a stratigraphical horizon lower than it does beyond those limits. It is to be noted that it is only within the same limits that there are conspicuous limestone workings *above* the sill, at Northfield and in the burn west of Quarter; these are presumably also in the Murrayshall ("D") Limestone, but there is no definite evidence on this point.

The Top Hosie with *Posidonomya corrugata* is still exposed at the south end of some old workings in the Chough Glen[1], where the Second Hosie was probably taken out at the same time. These two limestones are also exposed in the Castlerankine Burn near Linns[2], while higher upstream and close to the boundary-fault, a different, decomposed seam, may possibly be the Main Hosie. Further down the same burn, about half-a-mile W. of Rashiehill, the Top Hosie is again seen, and 200 yards from the steading a thin band of marine fossils, at the bottom of a small

[1] 'Explanation of Sheet 31,' *Mem. Geol. Surv.*, 1879, pp. 62 and 68, locality 194.

[2] *Ibid.* Locality 185.

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cliff of blaes, is probably the position of the Johnstone Shell Bed[1] which is faulted out of the Carron Section. The marine band in the "Black Metals," at a still higher horizon, is exposed in the Carron opposite the Herbertshire Paper Mill[2]. It consists of 3½ ft. of fossiliferous blaes, and the band of crushed *Naiadites*, found also at other localities a few feet higher in the sequence, is conspicuous at the same spot.

Many bores which are being put down in the coalfields and oil-shale fields have been visited by Dr. Lee. Two recently put down at Blackness, Linlithgowshire, in search of a north-western extension of the oil-shale fields of Linlithgowshire, have shown the absence of workable oil-shale in that district. The sequence is remarkable in the attenuation of the oil-shale strata between the Broxburn and the Pumpherston horizons. Particulars will be found in Appendix II. We are especially indebted to Mr. James Kidd, M.P. for Linlithgowshire, for permission to publish the results of these bores.

(3) Boring for Oil at West Calder.

The bore in search of petroleum which is situated about a quarter of a mile south of the village of West Calder, Midlothian, has now reached a depth of 543 fathoms, and is the deepest bore which has yet been put down in the Oil-Shale Series in Scotland. The West Calder district is included in six-inch Sheet Edinburgh 11 N.W., published in 1908, but of which a new edition is in preparation. A small anticline occurs to the south-west of West Calder and the oil-bore has been placed approximately on the summit of this anticline, which is about half-a-mile in diameter and gives place to synclines on the east and south. The important Calder fault has been traced on the east side of the anticline, but perhaps dies out as it runs south-westwards, as the dislocation of the outcrops of the oil-shale seams cannot be of great magnitude. At a distance of about half-a-mile to the south-west of the bore there are several small faults.

The bore starts immediately below the Broxburn Shale which has been mined to the outcrop a short distance to the west. At a depth of 50 to 55 fms. it passes through an oil-shale which is recognised by the mining engineers of the district as the Dunnet seam. About 73 fms. from the surface there is another oil-shale, which is probably the Under Dunnet, well known in the adjacent district[3], but frequently not of economic value. Thirty fathoms lower down there is a light-brown fresh-water limestone with entomostraca, apparently 10 to 12 ft. thick. This may be the Barracks Limestone, though that bed is

[1] 'Top Marine Band' of P. Macnair, 'The Hurlet Sequence,' etc., *Proc. Roy. Soc. Edin.*, vol. 38, pt. ii, 1917, p. 185.

[2] 'Explanation of Sheet 31,' pp. 62, 68 and 69, locality 192.

[3] 'Oil Shales of the Lothians,' *Mem. Geol. Surv.*, 2nd ed., 1912, p. 21.

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generally not well represented at West Calder. In other respects the upper portion of the bore does not differ from the sections recorded in other bores in the immediate vicinity. The deeper strata, however, have not been proved hitherto by boring at West Calder and the new record is of interest, not only as furnishing evidence of the exact geological sequence, but as differing somewhat from natural exposures in the neighbourhood.

The first recognisable horizon below the Barracks Limestone is the Burdiehouse Limestone, which was 15 ft. thick and was entered at 215 fms. It shows the usual characters, being a dark-coloured, fine-grained, fresh-water limestone. Between these limestones there are 110 fms., mainly sandstone with intercalations of dark shale, but although a thin oil-shale was found at 188 fms., there is no indication of any deposit of economic interest, and in the Camps Shale position above the Burdiehouse Limestone nothing of value was met with. For 63 fms. below the Burdiehouse Limestone there was a rather monotonous sequence of dark carbonaceous shales with a few beds of sandstone near the top, some marls and a thin dark limestone.

At 280 fms. a thick bed of greenish volcanic ash was encountered and this persisted to a depth of 418 fms. As a whole this ash-bed was uniform in composition, but occasionally it had an admixture of dark shale and at 375 fms. the rock-powder extracted from the bore showed traces of coal. The larger fragments in the ash were examined microscopically and proved to be olivine-basalt. From 418 to 433 fms. the bore passed through black shales, with a thin non-fossiliferous limestone of the type known in this district as a 'cement.' There another basaltic ash-bed was proved which persisted from 433 to 489 fms. Apparently it was free from admixed sediment. Below this there were 7½ fathoms of vesicular dark-green olivine-basalt, in a single lava-flow so far as was ascertained. From the base of this lava at 497 fms., black shales with a few thin seams of limestone or 'cement' extend to the bottom of the bore, a farther depth of 46 fms. The distance below the base of the Burdiehouse Limestone (217 fms.) is at present 326 fms., and is almost entirely occupied by black shales, basaltic ash-beds, and one lava-flow. None of the oil-shale seams that lie below the Burdiehouse Limestone, such as the Pumpherston, Dalmahoy, Wardie and Coalheugh Shales have been identified, but this was not unexpected as in no part of the surrounding country have they proved to be workable.

From a geological standpoint the striking feature of the bore record is the general character of the sequence below the Burdiehouse Limestone. In the nearest available section, that seen in the Murieston Water from Harburn to Skivo (from 2 to 4 miles distant) the sequence at this horizon consists largely of sandstone, with one oil-shale (the Coalheugh Shale), a limited amount of black carbonaceous shale and probably a few insignificant ashy beds[1]. Three miles to the south, in the Cobbin-

[1] 'Oil Shales of the Lothians,' *Mem. Geol. Surv.*, 2nd ed., 1912, p. 27.

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shaw district, these lower beds have been proved by bores and are visible in natural exposures. In that district the Pumpherston Shales are not workable, but there is a bed of volcanic ash, known as the Crosswood Ash, which may be on the same horizon as that which occurs in the West Calder bore. It is only 7 fms. thick, while in the bore under discussion there are 194 fms. of basaltic ash. At Crosswood also there is no lava-bed below the ashes. Other points of difference are that in the Cobbinshaw area there are frequent deposits of sandstone and shaly sandstone, a few thin encrinital limestones and intrusive sills of dolerite among the strata below the Burdiehouse Limestone, all of which are absent at West Calder, so far as the bore has yet proved.

III.—PETROGRAPHICAL WORK.

The work carried out in the Petrographical Department during the past year has been mainly connected with the preparation of a memoir on the petrography and chemistry of certain refractory materials, which is now in the press. Dr. Thomas has continued his work for the Research Department of the Admiralty and has reported upon matters of economic importance to Government departments and many private individuals. At the request of the Home Office, he furnished reports upon the microscopical and mineralogical characters of dust aspirated under special conditions from ganister-mines and other underground workings, after examination of some 50 samples.

The petrographical work connected with the survey of the Island of Mull, Moor of Rannoch and Ayrshire has been continued, and the study of the interesting xenolithic and sapphire-bearing composite sills of Mull has been resumed.

The petrography of the igneous rocks of Croft and adjoining areas has been undertaken by Mr. Whitehead for the memoir on the New Series Sheet 169 (Coventry).

The detailed petrography of Sheet 86, Scotland, is being dealt with by Mr. Read, and considerable progress has been made.

IV.—CHEMICAL WORK.

With reference to the work done in the laboratory, Mr. Ennos reports that the analyses of silica rocks and dolomites referred to in last year's 'Summary of Progress,' have been incorporated in 'Special Reports on the Mineral Resources of Great Britain,' Vol. XVI, which is now in the press. The analysing of a series of fireclays, 12 of which have been completed, has been commenced for another volume of these reports. Partial analyses of four iron-ores were made for Vol. XII of the reports, which deals with the iron-ores of Mesozoic and later formations. Three Scottish rocks previously examined for alkalis only, and a mineral from Ayrshire approximating in composition to kaolinite, have been analysed with the following results:—

Tourmaline-granite (pegmatite).—Vertical dyke in schists. Banffshire coast, west side of East Head, three-quarter mile

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north-east of Portsoy. One-inch sheet 96. Six-inch Banff. 4 N.W.

Slice No. S. 19628. Lab. No. 550.

Felspar-rock.—Vertical dyke, intrusive in Lewisian gneiss. Roadside at Cnoc an Tuir, halfway between Rhiconich and Achriesgill, north-eastern shore of Loch Inchard. One-inch map 113. Six-inch Sutherland 22 S.W.

Slice No. S. 19644. Lab. No. 552.

Large granite intrusion. Corrennie Quarry at Tillyfourie Railway Station, Aberdeenshire. One-inch map 76. Six-inch Aberdeen 63 S.E.

Slice No. S. 19626. Lab. No. 554.

Lab. No.	550	552	554
SiO_2	72·69	72·10	75·43
TiO_2	trace	trace	·32
Al_2O_3	14·46	15·14	13·06
Fe_2O_3	·72	·63	·69
FeO	not found	·05	·28
MnO	·10	·06	·11
CaO	·28	·27	·92
MgO	·03	·03	·12
K_2O	8·90	9·35	5·09
Na_2O	2·48	2·05	3·85
Li_2O	not found	not found	trace
H_2O at 105° C.	·05	·05	·06
H_2O above 105° C.	·23	·21	·20
P_2O_5	·23	·10	·07
Total	100·17	100·04	100·20

Anal. E. G. Radley.

Mineral in veins in Bauxitic Fireclay. Saltcoats shore, Ayrshire. 1 in. sheet 22. 6 in. Ayr. 16.

Museum No. 12138. Lab. No. 604.

	Lab. No. 604.	Kaolinite $H_4Al_2Si_2O_9$.
SiO_2	45·35	46·60
TiO_2	·16	—
Al_2O_3	39·13	39·49
Fe_2O_3	·86	—
FeO	not found	—
MnO	trace	—
CaO	·03	—
MgO	·20	—
K_2O, Na_2O	trace	—
H_2O at 105° C.	·43	—
H_2O above 105° C. ...	14·12	13·91
P_2O_5	·10	—
Total	100·38	100·00

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V.—PALÆONTOLOGICAL WORK.

England and Wales.

New ammonites and other fossils obtained by Mr. Pringle from borings in Norfolk have added materially to our knowledge of the Kimmeridge Clay and its zonal characterization. The subzone of *Saccocoma*, as indicated by the presence of the name-fossil, was recognised in the Virgatites Beds at localities near King's Lynn. The pyritized radial plates of *Saccocoma*, first found at this horizon in Kent and later in Dorset, have now been proved to have a wide distribution and to provide an important datum-line easily recognisable in borings.

The identification of certain fossils obtained from the Llanfyllin district has shown that the palæontological evidence is essential to the correct geological mapping of that area.

Some ammonites collected by Dr. Kitchin and Mr. Pringle from below the Interruptus Zone of the Gault south of Leighton Buzzard have been added to the Survey collections. They comprise species of *Leymeriella* and *Sonneratia*, which characterize the zone of *Leymeriella tardefurcata* (d'Orb.) in parts of France and Germany. The development of this zone in England had not been previously recorded, although attention had been drawn to its absence in Kent and in the Boulonnais.[1]

Much revision-work was carried out in the Museum by Mr. Allen before his retirement. He transferred to the exhibition-cases many type-fossils and other specimens formerly in the collection of the Geological Society.

The following specimens in the Museum have been figured and described:—

In the Palæontographical Society's Volume for the year 1917. (Published 1919).

A Monograph of the British Palæozoic Asterozoa.

By Dr. W. K. Spencer, M.A.

Platanaster ordovicus *Spencer*, text-figs. 114–118, 120, 121, p. 171.

The Fossil Fishes of the English Wealden and Purbeck Formations.

By Dr. A. Smith Woodward, F.R.S.

Pholidophorus ornatus *Ag.*, pl. xxi, fig. 4, pp. 103–105.

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[1] 'The Faunal Characters and Correlation of the Concealed Mesozoic Rocks in Kent,' Appendix i, in 'Summary of Progress for 1918,' *Mem. Geol. Surv.*, 1919, p. 45.

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A Monograph of the British Cambrian Trilobites.

By Mr. P. Lake, M.A.

? Eurycare sp., pl. xi, figs. 6–8, p. 94.
Peltura scarabæoides (*Wahl.*), pl. xi, figs. 9, 10, p. 97.
„ olenoides (*Salt.*), pl. xii, fig. 4, p. 100.
Beltella depressa (*Salt.*), pl. xii, figs. 6–8, 10, p. 104.
„ verisimilis (*Salt.*), pl. xiii, figs. 2, 2a, 3, p. 107.
Parabolinella simplex (*Salt.*), pl. xiii, fig. 6, p. 110.
Angelina sedgwicki *Salt.*, pl. xiv, fig. 1, p. 112.
Dikelocephalus discoidalis *Salt.*, pl. xiv, figs. 2–5, p. 115.
„ celticus *Salt.*, pl. xiv, figs. 8–10, p. 116.

In the Geological Magazine, Vol. VI, 1919.

By Mr. R. G. Carruthers.

Cryptophyllum hibernicum *R. Carr.*, pl. xi, figs. 1–4, 6, p. 436.

In the Transactions of the Royal Society of Edinburgh, Vol. LI.

The Forest of Wyre and the Titterstone Clee Hill Coal Fields.

By Dr. R. Kidston, F.R.S.

Cingularia typica *Weiss*, pl. i, figs. 2, 2a, p. 1042.
„ cantrilli *Kidst.*, pl. i, figs. 3, 3a, 4, 4a, 5, 5a, p. 1045.
Sigillaria reticulata *Lesqx.*, pl. ii, figs. 1a-c, p. 1055.
„ transversalis *Brongt.*, pl. ii, figs. 2, 3, 3a, 4, p. 1054.
„ pringlei *Kidst.*, pl. iii, figs. 1, 1a, p. 1053.
„ nudicaulis *Boulay*, pl. iii, figs. 2, 2a, p. 1050.
„ *cf.* „ pl. iii, figs. 3, 3a, p. 1051.
„ candollei *Brongt.*, pl. iv, figs. 1, 1a, 2, 2a, p. 1049.
„ boblayi *Brongt.*, pl. iv, figs. 3, 3a, p. 1048.
„ distans *Sauveur*, pl. iv, figs. 4, 4a, p. 1051.
Lepidophloios acerosus (*L. & H.*), pl. ii, fig. 5, p. 1057.
Annularia spicata (*Gutbier*), pl. ii, figs. 6, 6a, 7, 7a, p. 1039.
Carpolithes areolatus (*Boulay*), pl. v, figs. 1, 1a, p. 1062.
„ membranaceus *Göppert*, pl. v, figs. 8, 9, p. 1060.

Contributions to our knowledge of British Palæozoic Plants.

Part I, Fossil plants from the Scottish Coal Measures.

By Dr. R. Kidston, F.R.S.

Sigillaria elegans (*Sternb.*), pl. iii, figs. 8, 8a, p. 711.

In the Journal of the Cincinnati Society of Natural History, Vol. XXII, No. 2.

Notes on Richmond and Related Fossils.

By Dr. Aug. F. Foerste.

Orthis (Dinorthis) retrorsa *Salt.*, pl. ii, figs. 1a, b, c, p. 48.
„ („) inflata *Salt.*, pl. ii, fig. 1d, p. 48.
„ (Hebertella) llandiloensis *Foerste*, pl. ii, figs. 1e, f, g, h, ; pl. iii, figs. 3, 3a, 3b. p. 49.

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Scotland.

Fossils were collected chiefly from the Carboniferous Limestone areas of Ayrshire, which are now undergoing revision. Several borings were visited and portions of cores were also sent to the Office by coal-masters, with requests for information, which it was possible to supply.

Since resuming palæontological work Dr. Lee has been engaged principally in revising existing exhibits and preparing new material for exhibition in the Survey Gallery of the Royal Scottish Museum.

VI.—PHOTOGRAPHIC WORK.

No photographs were taken in England and Wales owing to the absence of the photographer on military duty.

In Scotland 175 photographs were taken in illustration for the geology of the Argyll, Ayr, Forfar, Aberdeen and Banff districts.

VII.—MUSEUM OF PRACTICAL GEOLOGY.

Although nominally closed during the greater part of the war, the Museum has been open to all who had definite enquiries to make. It was reopened to the public on April 1st, 1919, but the open evenings have been changed from Saturdays and Mondays to Saturdays and Thursdays. The mineral, fossil and rock-galleries are now accessible, but it has not been possible to bring up the ground-floor exhibits to their normal condition.

Exhibits of refractories, of rocks yielding oil and of natural oils have been prepared, and a series illustrative of chrysotile asbestos from South Africa and Canada. Examples of iron-ores, collected during the previous year, are being incorporated in a revised exhibit of British Iron-Ores.

A selection of stones suitable for war memorials was lent to the War Memorial Exhibition held at the Victoria and Albert Museum, and later at the Royal Academy. Many enquiries have been received on the subject of stones for memorials.

List of Donations during the year 1919.

Andrews, C. T., Esq.—Group of quartz-crystals from Congonhas de Campos, Minas Geraes, Brazil.

Ashcroft, F. N., Esq., M.A., F.C.S., F.G.S.—A series of minerals from Derbyshire and Cumberland. A series of specimens of zeolites.

Ashcroft, Miss M. E. M.—Dark-purple fluor containing a crinoid.

Dick, Allan B., Esq.—Four specimens of slags, silica from Cornwall.

Fitzmaurice, C. E. A., Esq.—Antimony and silver-lead ores from the Trevinnick Mine, Cornwall.

Gilbert, C. J., Esq., F.G.S.—Sun-cracks on sand-rock from the High-level Gravels at Little Heath, Berkhamsted.

Godden, R. A., Esq.—Island Phosphate from Curaçoa.

Green and Sons, Ltd., Messrs. J. G.—Sandstone from the Denwick Quarries, Alnwick.

Gregory, Messrs. J. R.—Phosphoro-calcite.

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HORSHAM URBAN DISTRICT COUNCIL.—Samples of the Strata from the bori at the Horsham Waterworks, 1903–4.

JONES, F. T., ESQ.—A series of minerals from Alderley, Cheshire.

KENDALL, PROF. P. F., M.Sc., F.G.S.—Sandstone intrusion in coal, 'rock-rolls contorted sandstone from a true 'wash-out' in the coal; sandstone 'drop from the roof into the coal-seam.

KENNY, W. H., ESQ.—African Minerals.

LECKHAMPTON QUARRIES CO., LTD.—Samples of limestone, 'Cotswold Dale Stone.

MARSHALL, F., ESQ.—Quartz coated with nail-head pyrites, Cornwall.

PRESTEA BLOCK A., LTD.—Gold-bearing quartz from the Gold Coast.

RENWICK, R., ESQ.—(*See* Horsham Urban District Council.)

ROGERS, DR. A. W.—A collection of Asbestos minerals from South Africa.

RUSSELL, ARTHUR, ESQ.—Copper-ores from Alderley Edge. Niccolite from Kirkcudbrightshire.

RUSSELL, F., ESQ., F.G.S.—A cast of a large *Bellerophon* from the dolomitic Carboniferous Limestone of Breedon Cloud.

RYLAND, F. J., ESQ.—Barytes from the Barlocco Mine, Auchencairn, Dalbeattie, and from the Potts Ghyll Mines, Cumberland.

SANDISON, REV. R. C.—Three specimens from the Chromite Quarries, Balta Sound, Unst, Shetland.

SKINNINGROVE IRON CO., LTD.—Artificial apatite.

TAYLOR, CAPTAIN W.—Scheelite and wolfram with mispickel, East Pool Mine, Cornwall.

TRUEMAN, DR. A. E., F.G.S.—Specimen of dark micaceous shale with lamellibranchs, from the *Oistoceras* sub-zone (top of Lower Lias) of Bracebridge, south of Lincoln.

VARCOE, R. W., ESQ.—China-stone with tourmaline, Cornwall.

WALEY, F. R., ESQ.—Several small specimens of ancient marbles; specimens of sal ammoniac, ruby, emerald, oil-shales, etc.

WALFORD, E. A., ESQ., F.G.S.—A *Rhynchonella* from the Great Oolite of Aynho.

WORTH, R. H., ESQ., F.G.S.—Montmorillonite from near Meldon, Devon.

ZAFFERE, P., ESQ.—Gold Ore, Alpes Mine, Southern Rhodesia.

VIII.—MAPS AND MEMOIRS, ETC., PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

ENGLAND AND WALES.

I.—MAPS.

Six-inch reference Maps.

The following 35 standard copies of Six-inch quarter-sheets have been made from the field copies, and are available for reference:—

Cumberland, 48 N.W., N.E., S.W., S.E.

Kent, 2 S.W., S.E.; 8 N.W., N.E., S.E.; 9 S.W.

London, 1 S.E.; 10 S.W.; 11 S.W., S.E.

Pembrokeshire, 38 N.E., S.E.; 39 N.W., N.E., S.W., S.E.; 40 N.W., N.E. S.W., S.E.; 41 S.W., S.E.; 42 N.W., N.E., S.W., S.E.; 43 N.W., N.E. S.W.; 44 N.W., N.E.

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II.—Memoirs:

Published Memoirs.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1918, 70 pp.; 3 text figures. Price 2*s.* 6*d.* net.

Special Reports on the Mineral Resources of Great Britain:—

Vol. VIII.—Iron Ores: Hæmatites of West Cumberland, Lancashire, and the Lake District. By Bernard Smith, M.A., 182 pp., 4 plates; 29 text-figures. Price 9*s.* net.

Vol. IX.—Iron Ores (*contd.*): Sundry Unbedded Ores of Durham, East Cumberland, North Wales, Derbyshire, The Isle of Man, Bristol District and Somerset, Devon and Cornwall. By T. C. Cantrill, B.Sc., R. L. Sherlock, D.Sc., and Henry Dewey, 87 pp.; 7 text figures. Price 3*s.* 6*d.* net.

Vol. X.—Iron Ores (*contd.*): The Hæmatites of the Forest of Dean and South Wales. By T. Franklin Sibly, D.Sc., 93 pp.; 14 text-figures. Price 4*s.* net.

The Geology of the Country around Lichfield, including the Northern Parts of the South Staffordshire and Warwickshire Coalfields. (Explanation of Sheet 154.) By G. Barrow, W. Gibson, D.Sc., T. C. Cantrill, B.Sc., E. E. L. Dixon, B.Sc., and C. H. Cunnington, B.Sc., with contributions by J. B. Hill, R.N., T. Eastwood, A.R.C.Sc., and J. Pringle, 302 pp.; 1 plate; 6 text figures. Price 9*s.* net.

SCOTLAND.

I.—Maps.

Six-inch Reference Maps.

The following copies of six-inch maps have been completed and deposited in the office for reference:—

Inverness, 20; 155 N.W., N.E., S.W.
Kincardine, 1 N.E., S.W., S.E.; 2 S.W., S.E.; 10, 11, 15, 16; 18 N.E., S.E.; 19, 20; 22 N.E., S.E.; 23, 24; 26 N.W., N.E., S.E.
Nairn, 6.
Perth, 16 S.W.; 17.
Renfrew, 4 S.W.

The following clean copies, deposited provisionally in 1915–16 owing to the absence of officers on active service, have been checked, revised and deposited in the office for reference:—

Argyll, 10, 11, 19; 30 N.W., S.W., S.E.; 31, 32; 43 N.W., N.E., S.E.; 45, 46, 57, 59, 60.

Inverness, 150 N.E., S.W., S.E.; 151, 152, 159 S.E.; 160, 161, 162, 165 N.E.; 166, 167 N.W., N.E.; 168 N.W., N.E., S.E.

The revision work of the Silurian areas of the Southern Uplands of Scotland has been added to the following six-inch clean copies (Old Series Maps), and these are now completed and deposited in the office for reference:—

Kirkcudbright, 28 N.W., N.E., S.E.; 29.

Wigtown, 5, 6, 7, 8 N.W., S.W., S.E.; 9, 10, 11, 12, 13, 14 S.W.; 15, 16, 17, 18, 19, 20, 21 N.W., N.E., S.E.; 22, 23 N.W., N.E., S.E.; 24, 25, 26, 27, 28 N.E.; 29, 30, 31 N.W., N.E., S.E.; 32 N.W., S.W.; 33 N.W., N.E., S.E.; 34; 35 N.W., S.W.; 36 N.W., S.W., 36a N.W.; 37 N.W., N.E.

II.—Memoirs.

Published Memoirs.

Summary of Progress for 1918. *See* above.

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APPENDIX I.

On a boring for Coal at Brayton Domain Colliery, Cumberland.

By Bernard Smith, M.A.

Brayton Domain Colliery is situated about 2 miles N.E. of Aspatria. The Coal Measures are reached by sinking through St. Bees Sandstone, which forms the northern limit of the exposed coalfield. The accessibility of the concealed coalfield was discussed in the Final Report of the Royal Commission on Coal Supplies, Part IX, p. 17 (1905), and it was concluded that a fault which was supposed to introduce the St. Bees Sandstone along the whole of this margin of the coalfield, must be small, if it exists, at Brayton and east of it. The explorations described in the following pages provide no evidence of such a fault. On the contrary they show that the St. Bees Sandstone is of trifling thickness near the margin, but increases rapidly northwards. A more serious obstacle to reaching the coal, however, lies in the increasing thickness of barren red measures in that direction.

At No. 4 Pit, Brayton, the Yard Band Coal of the Middle Coal Measures is worked at a depth of about 552 ft., on the south-west side of a fault with a downthrow of 30 fms. south-west (Fig. 2). To the east of this fault, where the coal has been worked, the Heathfield borehole proved the top of the Yard Band Coal, 4 ft. 6 in. in thickness, at a depth of 561 ft. 8 in. from the surface; the grey productive measures being overlain by 22 ft. of boulder clay on 46 ft. 5 in. of St. Bees Sandstone, on approximately 292 ft. 5 in. of unproductive (supposed Upper) Coal Measures. A little farther east a large fault with north-eastward downthrow has been touched in the workings at 80 fms. depth.

To prove the ground beyond this fault, borehole No. 1 was put down. This passed through 100 ft. of boulder clay, 456 ft. 4 in. of St. Bees Sandstone, and 706 ft. of unproductive measures, a total of 1,262 ft. 4 in., when the boring was abandoned owing to difficulties. Borehole No. 2 was then commenced slightly north of east of No. 1. Passing through much the same sequence it entered grey productive measures at 1,384 ft. 3 in. and passed through the top of the Yard Band Coal (3 ft. 9 in.) at 1,855 ft. 11 in., the bottom of the boring being at 1,870 ft.

Farther evidence as to the lie of the Yard Band Coal in this area being required, another boring, No. 3, was decided upon. By March, 1918, this boring had reached a depth of 2,050 ft. and was still in unproductive measures, when the Geological Survey was invited to examine the cores with a view to helping in a decision whether these measures should be assigned to the Upper Coal Measures or to some other formations. We are indebted to Mr. G. H. Askew, and to Mr. Thomas Eadie, the Colliery Manager, for valuable records of other borings and workings in the vicinity.

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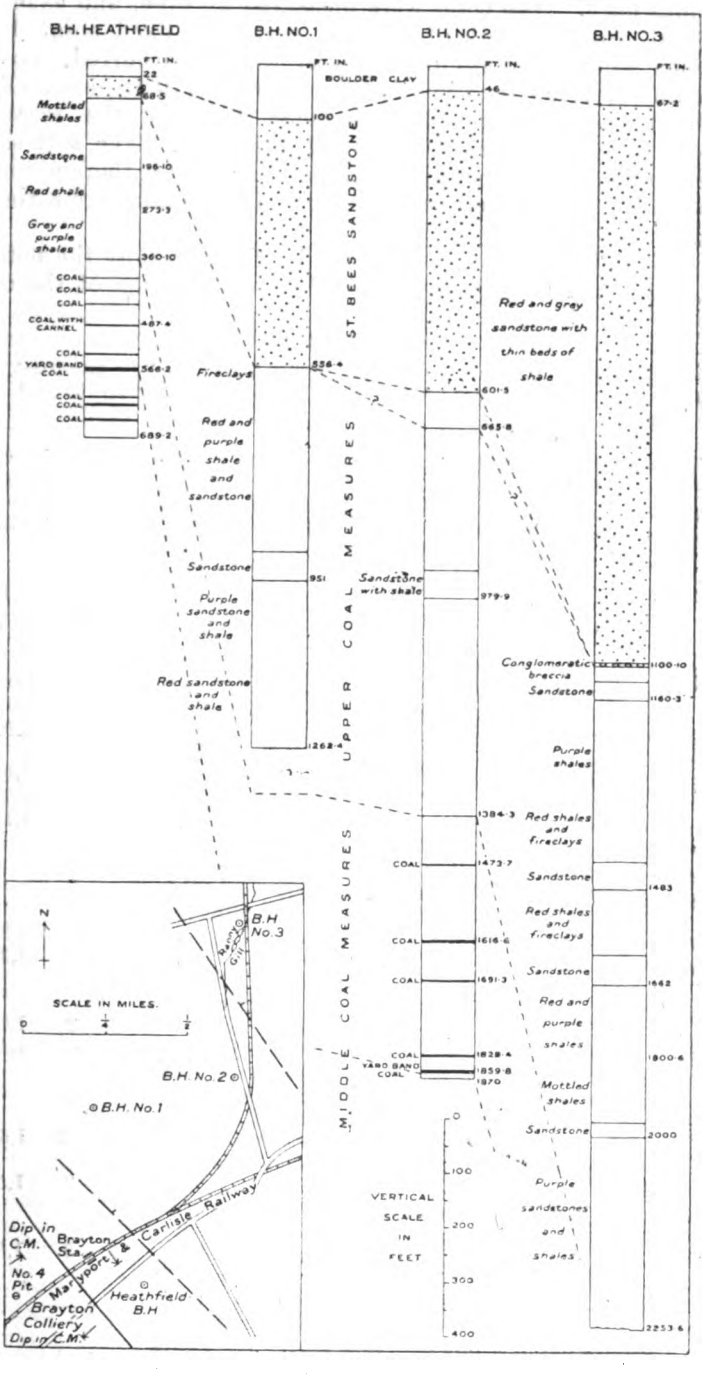
FIG. 2.—BORINGS FOR COAL AT THE BRAYTON COLLIERY, CUMBERLAND.



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Only the cores below 1,000 ft. had been kept in order, th remainder having been scattered. As no depths were marke on them, it was possible, in many cases, to give approximat positions only. The cores were measured by tape, and examine in detail, from a depth of 2,081 ft. upwards, fixed points being obtained where changes in diameter of core occurred, namely, at depths of 1,789 ft. 3 in., 1,296 ft., and 1,170 ft. 4 in. From these points adjustments were made between the measured lengths and the recorded depths of the cores. The soft shales gave trouble to the borers by caving in; hence there are many gaps in the record, and cementation was necessary from time to time.

To the following record provided by the Company the notes in square brackets have been added after examination of the cores.

Borehole No. 3 (*Fig.* 2).

This boring is situated at Ranny Gill, about ¼ mile S.E. of Langrigg. New Series one-inch Ordnance Map, Sheet 23; Old Series Geological 101 N.E. Six-inch Geological, Cumb. 28 S.W. Lat. 54° 47′5″. Long. 3° 17′8″.

Height of surface above O.D., 90 ft.

The boring, by diamond-drill, commenced 1916. Bottom of 5½ in. core at 1,170 ft. 4 in., of 4½ in. core at 1,296 ft., of 3½ in. core at 1,789 ft. 3 in. Remainder 2¾ in. core. The dip in the St. Bees Sandstone is generally less than 6°; in the shales beneath it varies from 15° to 30°, and in a sandstone at about 1,434 ft., it reaches 35°.

	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
GLACIAL:—				
Gravel, sand, boulders and pinnel	67	2	67	2
ST. BEES SANDSTONE:—				
Red, occasionally grey, sandstone, with numerous beds of brown [red] shale	1,002	10	1,070	0
Purple sandstone [grey at base]	26	10	1,096	10
Stone (bastard) [conglomeratic breccia]	4	0	1,100	10
UPPER COAL MEASURES:—				
Purple sandstone and shale	5	9	1,106	7
Brown shale [purple]	21	5	1,128	0
Purple sandstone [micaceous, with a little shale] ...	32	3	1,160	3
Brown shale, with a little purple and grey shale and grey and red sandstone, with gypsum veins at base [some of the above shales are purple, others are reddish purple or of a dull *brick-red* tint. A micaceous red sandstone occurs at approx. 1,210 ft.]	149	11	1,310	2
Grey sandstone	1	2	1,311	4
Brown shale [mainly purple shales, occasionally sandy, some *red*, some mottled green. Some like fireclay in beds 2 to 3 ft. thick]	122	8	1,434	0
Brown sandstone [purple shaly micaceous sandstone] ...	49	0	1,483	0
Brown shale [red purple sandy shales, on same with lamellibranchs and occasional rootlets. Occasional ribs red sandstone and beds *red* shale and of fireclay; on purple shales with sandstone; on *indian red* shales]	37	6	1,520	6
Brown sandstone [purplish micaceous sandstone with rootlets]	6	3	1,526	9
Brown shale (broken) [red shales and occasional purplish mudstones, with 1 ft. sandstone. Some beds like fireclay, with sandstone pebbles]	27	2	1,553	11
Brown and grey sandy shale on brown shale [red shales on *indian red* mudstones, shales and fine sandstones. Some *red* and purple fireclay with sandstone pebbles; on reddish-purple shales and sandstone. Mudstones and shales occasionally *bright brick-red* and fine-grained]	35	8	1,589	7

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	Thickness. Ft.	In.	Depth. Ft.	In.
Brown sandstone [reddish purple sandstone on purple micaceous sandstone with red joints]	7	6	1,597	1
Brown shale [purple shales on reddish purple fireclay (3 ft.) on variegated purple shales with pebbles and fragments of red shale]	10	1	1,607	2
Brown sandstone tinged with blue [purple]	5	7	1,612	9
Reddish-grey sandstone [grey-purple and micaceous] ...	49	3	1,662	0
Brown and grey shale (3 ft. 10 in.) on grey-blue and brown shale [purple shales, occasionally sandy, on grey or mauve shales with fragments hæmatite and red shale. Occasional beds like fireclay, with rootlets]	24	1	1,686	1
Brown sandy sandstone [purple, brown and *salmon* shales, occasionally purple; dip about 30°]	76	5	1,762	6
Brown shale (a little sandstone at 1793–4 ft.) [purple and reddish-purple micaceous shales and mudstones; dip 20°]	38	0	1,800	6
Grey sandstone [purple]	0	8	1,801	2
Purple shale [red mudstone]	2	5	1,803	7
Brown shale [red and purple mudstones, mottled green near base]	24	9	1,828	4
Brown shale [purple and *red* mudstones, some mottled]...	5	4	1,833	8
Brown sandy shale [purple micaceous shaly sandstone]	9	8	1,843	4
Brown shale [purple shales, some sandy and micaceous and slickensided]	12	3	1,855	7
Grey flint (very hard) [grey quartzitic sandstone] ...	0	7	1,856	2
Brown shale [purple mudstones (3 ft.) on *indian-red* mudstones and shales, occasionally purplish amd micaceous]	32	3	1,888	5
Brown shale tinged with blue [purplish, sandy and micaceous, mottled green]	9	2	1,897	7
Brown shale [reddish purple, sandy and micaceous, with gypsum]	5	0	1,902	7
Brown shale (broken) [purplish and sandy; slickensided]	15	8	1,918	3
Brown shale [purple and sandy, gypsum in joints; dip 35°]	3	10	1,922	1
Dark grey sandstone [purple-red siliceous sandstone] ...	7	4	1,929	5
Brown shale [mottled purple mudstones, and purple-red sandstone with gypsum, on red-purple mottled mudstones, on blue-purple ditto]	23	1	1,952	6
Hard brown stone [siliceous sandstone]	0	3	1,952	9
Brown and grey shale [purplish-red mudstones, mottled green]	18	0	1,970	9
Brown shale [sandstone, 30 ft., some speckled; on marls and shales]	60	7	2,031	4
Brown shale with a little grey shale [reddish-purple shales]	8	5	2,039	9
Brown sandstone mixed with grey [mottled mudstone, etc.]	25	6	2,065	3
Red sandstone [purplish]	1	1	2,066	4
Brown shale [„]	1	0	2,067	4
Red sandstone [„]	2	9	2,070	1
Red and grey sandstone full of mica [purplish-red shale with greyish sandstone bands, very micaceous and ripple-marked. Some purplish sandstone; dip 20°]	8	3	2,078	4
Red sandstone mixed with grey [medium grained purple, micaceous, felspathic false-bedded sandstone, layers nearly horizontal]	15	2	2,093	6
Total depth bored April 14, 1919, *was* 2,086 *ft.*				
Blue sandy shale	1	3	2,094	9
Red sandstone mixed with grey	2	9	2,097	6
Brown shale and grey sandstone	63	8	2,161	2
Grey shale	0	4	2,161	6
Grey sandstone and brown shale	1	9	2,163	3
Brown shale and sandstone	16	4	2,179	7
Brown and grey shale with mica	3	11	2,183	6
Brown sandstone with mica	3	0	2,186	6

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	Thickness. Ft.	In.	Depth. Ft.	In.
MIDDLE COAL MEASURES ? :—				
Brown and blue shale	10	9	2,197	3
Grey sandstone	0	4	2,197	7
Brown and grey sandy shale [red and greyish-purple micaceous sandstone and shale; dip of shales, 15°] ...	20	5	2,218	0
Blue brown shale	10	3	2,228	3
Grey brown shale	3	7	2,231	10
Blue and grey shale	3	0	2,234	10
Brown and blue shale	1	0	2,235	10
[Not reported]	1	8	2,237	6

Total depth bored, measured by rods, Feb. 11, 1920, *was* 2,253 ft. 6 in.

Boring was stopped at this point and the hole cemented up, as a great quantity of dirt was dropping to the bottom.

In the above record the base of the St. Bees Sandstone has been placed at the bottom of a 4 ft. bed of conglomeratic breccia; the immediately overlying purple and grey sandstones being, apart from colour, similar in character to the red and grey sandstones of higher horizons. There being a difference in the level of this base of about 500 ft. between this boring and B.H. No. 2, it is clear that a post-Triassic fault of considerable throw intervenes.

The conglomerate consists mainly of rounded and subangular fragments set in a grit with a dolomitic matrix. The larger fragments include pebbles of marl (some ironstained), dolomite, dolomitic marl and silty marl. Some of the marly fragments appear to contain organic structures. The grit includes round and angular grains of clastic quartz, grains of silty marl, occasional felspars with albite twinning, crushed quartzite and mica.

With regard to the beds below the breccia, few of the shales are brown; the majority are of purple hue, occasionally bluish-purple, but more usually reddish-purple. Red mudstones and shales occur at intervals down to nearly 1,900 ft. Some of them are chocolate-red, when dry; others bright brick-red, when wet. Their occurrence suggests that the colouring of part at least of the series is original, and not due to secondary staining. Purplish mudstones or clays, traversed by rootlets and resembling fireclays, both in appearance and mode of weathering, occur at several horizons, but are rarely more than 3 ft. in thickness. They contain pebbles of sandstone and marl of irregular shapes.

At lower levels the mottled shales or mudstones are distinctive. They frequently present an appearance of being brecciated, and contain small pebbles of marl, sandstone, and occasionally hæmatite. A specimen from approximately 2,048 ft. was sliced, and proved to be a patchy mudstone, of which the paler portions are sericitic paste rock with some chlorite, whilst the darker portions are ironstained. The brecciated appearance in a hand-specimen is due chiefly to the unequal segregation of iron-oxide. There were a few quartz-grains and a little carbonate material.

The sandy beds are of a purplish tint as a rule, although some are reddish, whilst the more siliceous members vary from greyish-

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purple to grey. The speckled purplish-red sandstone at about 2,020 ft. is a distinctive type, which might be recognised in neighbouring boreholes. The specks are possibly due to iron; they do not appear to be manganese.

The occurrence of bluish shales in the lower 50 ft. of the record suggests that the productive Middle Measures may possibly have been entered.

In conclusion, the lithological types are similar to those found in neighbouring boreholes, and to those attributed to the Upper Coal Measures in the Midland Coalfields. They also compare closely with the Red Sandstone Group or Upper Coal Measures of the Canonbie Coalfield[1], as shown in the records of the Roanburn and Forge borings.

The lamellibranchs occurring between 1,483 and 1,520 ft. 6 in. are poorly preserved, and have been identified by Mr. J. Pringle as *Anthracomya?* They are closely similar to certain ill-preserved shells referred to *Anthracomya* found in the Keele Beds at Thurgarton (1,037 ft.) by Dr. W. Gibson[2], and at Farnsfield (855 ft.) by Prof. H. H. Swinnerton[3]. They also occur commonly in the Newcastle Beds.

There seems to be little doubt, therefore, that these beds are in the main of Upper Coal Measure Age, and form part of the Whitehaven Sandstone Series, as argued by Mr. J. D. Kendall[4].

The following points arise for discussion:—

1. Is the Whitehaven Sandstone Series unconformable to the Productive Measures?
2. What is the significance of the northward thickening of that series beneath the New Red Sandstone?

1. The colours of these beds appear to be, in the main, original. Their base, as pointed out by Kendall, is difficult to detect, because they are of similar lithological types to the Middle Coal Measures, and subject to rapid variations. The colour is no guide, for the purplish or reddish tint may or may not extend to the base at all points, and may in some cases occur even in the higher parts of the productive measures, as at Buckley in Flintshire, and to a small extent also in the Warwickshire Coalfield; or even at lower horizons, as in the case of a group of 189 ft. of red sandstones and shales that occurs nearly 1,000 ft. down in the grey measures at Wallingwells (Firbeck Colliery) on the borders of Yorkshire and Nottinghamshire, and generally between Rotherham and Retford. The 'Rotherham Red Rock,' again, with which the Whitehaven Sandstone has been compared, is now considered to include one or more rocks[5], not necessarily at the same horizon, in the Middle Coal Measures.

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[1] *Trans. Royal Soc., Edinburgh*, vol. xl, pt. iv (No. 32), 1903, pp. 858–865, and 'Summary of Progress' (*Mem. Geol. Surv.*) for 1902, 1903, pp. 214–6.

[2] Unpublished.

[3] Unpublished, but specimens preserved in the Palæontological Department of the Geological Survey.

[4] 'The Whitehaven Sandstone Series,' *Trans. Fed. Inst. Min. Eng.*, vol. x, 1895–96, pp. 202–224.

[5] Prof. P. F. Kendall, *Final Rep. Roy. Com. on Coal Supplies*, part ix, Appendix iii, 1905, p. 22.

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J. D. Kendall maintains that there is a considerable unconformity between the two groups. His conclusion is based partly upon lithology and colour, but largely upon the varying thickness between the Yard Band Coal and the supposed base of the Whitehaven Sandstone Series at different points, and also on the supposed persistence of two coal-seams near the base of the Whitehaven Sandstone Series in the northern area.

The fact remains, however, that the base of the series cannot at present be fixed either by fossil evidence or by lithological character, and the absence of certain coals, near the top of the Middle Coal Measures, is at best negative evidence, and may be due to impersistence.

Newell Arber[1] claimed that the lower 200 ft. at least of the Whitehaven Sandstone Series was of Middle Coal Measure age, and that the unconformity, if present, between the Sandstone Series and the Productive Measures does not mark any considerable interval in geological time.

The Whitehaven Sandstone Series proved in the Brayton No. 3 borehole consists largely of shales, the proportion of shale to sandstone being roughly as 75:25, figures that agree with Kendall's estimate of the proportions in the series in this area.

2. At Frizington Hall, near Whitehaven, 531 ft. of Whitehaven Sandstone has been proved by boring[2]. The top had been denuded, but Arber estimated the full original thickness to have been at least 600 ft. At Brayton No. 3 boring a vertical depth of over 1,000 ft. of these rocks has already been penetrated, representing a true thickness of about 900 ft.

The Brayton boreholes show an increase in thickness (measured vertically) in a northerly direction of about 800 ft. in a little over one mile. Dips measured on the cores of No. 3 give an average difference of about 15° between the dip of the St. Bees Sandstone and that of the underlying strata. If we assume that these Carboniferous Rocks were dipping northwards towards the centre of the Carlisle Basin before the deposition of the New Red Sandstone and the occurrence of later faulting, a dip of this amount over a horizontal distance of a mile would give an increased (vertical) thickness of about 1,420 ft. Hence the difference in dip provides a sufficient explanation of the increase in thickness (without considering possible movements at different dates along fault-lines), even if we take it that the direction of dip of the beds was rather north-north-westward than true north.

The conclusion seems to follow that should the above rate of thickening continue northward, together with an increasing depth of Triassic cover, the productive Middle Coal Measures will be carried down rapidly to depths at which they cannot be reached and worked with profit.

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[1] 'The Fossil Flora of the Cumberland Coalfield, and the Palæobotanical Evidence with regard to the Age of the Beds,' *Quart. Journ. Geol. Soc.*, vol. lix, 1903, pp. 1–22.

[2] 'The Whitehaven Sandstone Series,' *Trans. Fed. Inst. Min. Eng.*, vol. x, 1895–6, pp. 215–216.

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APPENDIX II.

On the North-Western corner of the Lothian Oil-shale Field.

By G. W. Lee, D.Sc.

The north-western corner of the Scottish Oil-shale Field, consisting of an area of some two or three square miles around Blackness village (Six-inch Sheet, Linlithgow, 2 S.W.), has long been of interest to all connected with the oil-shale industry. Little was known of the district, as testified by the fact that the existing geological maps do not carry the lines of crop of the workable shale seams much further west than Philpstoun, but the simple structure of the ground, the geologically high position of the strata, and the continuity of the district with the valuable Philpstoun shale-field, were regarded as offering distinct possibilities of untapped resources[1]. Recent boring operations were therefore closely followed by the Geological Survey. The results were unsatisfactory from the mining point of view, but of considerable geological interest, and we have to express our indebtedness to Mr. J. Kidd, M.P., for his permission to make use of the information obtained.

No. 1 bore was put down on the west bank of the Black Burn, $\frac{1}{8}$ mile S.E. of Blackness, and No. 2 bore in a little quarry on the shore, 500 yards west of Blackness. As there is on the whole an ascending sequence from east to west, the second bore starts in a newer stratum than the first, and as it was carried down to the same horizon it offers the fuller sequence.

The following is condensed from the borer's log:—

	Thickness.			Depth.		
	Fm.	ft.	in.	Fm.	ft.	in.
Rubbish, blaes[2] and balls	–	–	–	3	3	0
Dark-grey limestone	0	1	6	3	4	6
Strata (mostly blaes)	4	–	–	6	1	9
Oil-shale	0	0	4	6	2	1
Sandstone	–	–	–	–	–	–
Limestone, brown earthy	0	0	3	6	3	9
Strata (mostly fakes and sandstone)	–	–	–	11	4	9
Blaes	–	–	–	16	4	6
Sandstone, fakes, blaes and ironstone	–	–	–	37	0	6
Black blaes	3	2	7	40	3	1
Dark-grey shale with fossils	0	5	0	41	2	1
Strata, mostly blaes with four beds of sandstone and a teschenite-sill 160 ft. thick	–	–	–	97	0	0
Shaly blaes and grey blaes	1	3	6	98	3	6
Dark-grey blaes with limy ribs and balls	2	2	2	100	5	8

[1] 'The Oil Shales of the Lothians,' *Mem. Geol. Surv.*, 2nd ed., p. 65.

[2] For explanation of terms used by Scottish borers, *see* p. 34, footnote.

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	Thickness. Fm.	ft.	in.	Depth. Fm.	ft.	in.
Strata (mostly blaes and fakes)	–	–	–	109	3	8
Ash	1	3	1	111	0	9
Strata	–	–	–	112	3	10
Ash	0	4	2	113	2	0
Blaes	–	–	–	120	5	1
Limestone and ironstone	0	0	6	120	5	7
Shaly blaes	0	1	4	121	0	11
Fakes	0	1	4	121	2	3
Coal	0	1	2	121	3	5
Marl	7	3	11	129	1	4
Fakes and fireclay	–	–	–	130	2	8
Coal plies	0	0	1	130	2	9
Fireclay, fakes, blaes	–	–	–	139	1	0
Coal	0	0	3	139	1	3
Fakes	–	–	–	141	1	0
Sandstone	5	5	6	147	0	6
Fakes and sandstone and faky blaes	–	–	–	154	3	6
Blaes	0	3	6	155	1	0
Limestone	3	3	11	158	4	11
Greenish marl	0	0	5	158	5	4
Strata, mostly burnt blaes	1	2	10	160	2	2
Coaly blaes, burnt	0	1	9	160	3	11
White whin and burnt blaes	–	–	–	162	2	5
Limestone	1	2	3	163	4	8
Fakes and sandstone	4	5	6	168	4	2
Sandstone	4	3	0	173	1	2
Strata, mostly fakes	–	–	–	180	5	2
Blaes with a layer of large *Estheria*	5	4	0	186	3	2
Black limestone	0	0	3	187	0	2
Sandstone, fakes and clay	2	0	0	189	0	2
Limestone	5	4	1	194	4	3

(Bore stopped in limestone.)

The limestone at the depth of 3 fathoms 4 ft. 6 in. is hard, grey, crinoidal and contains remains of *Productus*, *Lingula*, and other fossils. Its characters agree with those of the Riccarton Limestone, which lies not far below the Cobbinshaw position[1]. It is to be noted that in the West Calder district a thin crinoidal limestone has been met with 25 fms. below the Cobbinshaw ('Hurlet') Limestone and Coal.

The black blaes at 40 fms., which have been burnt by the sill lower down, are of a sufficiently fine texture to be regarded as having possibly once been of the nature of oil-shale. The blaes which underlie them are of marine origin and contain remains of goniatites. It is a significant fact that goniatites have been found below the Fraser Shale position in the West Calder district, and that the distance between that shale and the crinoidal limestone is there almost the same as in the Blackness boring, viz.—about 40 fms. The inference is that this burnt blaes represents the Fraser Shale. The next stratum of interest is the "shaly"

[1] 'The Oil Shales of the Lothians,' *Mem. Geol. Surv.*, 2nd ed., 1912, p. 65.

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blaes, or poor oil-shale at 98 fms. A marine fossiliferous bed underlies it, in which goniatites and the lamellibranch *Posidonomya becheri* are conspicuous. These fossils, again, are known from under the Raeburn Shale. That this 'shale' is the Raeburn is all the more probable when its position is considered relatively to that of the bed taken to be in the Fraser Shale position, and to that of the Two-Foot Coal—the next recognisable index: in both cases after deduction of the sill the distances agree well with the distances between these seams in the West Calder district. The position of the Two Foot Coal is clearly represented by the impure coal at 121 fms., and the Houston Marl is developed with the usual characters. The above remarks show that in the Blackness district the strata between the base of the Carboniferous Limestone and the base of the Houston Marl possess the development and aspect of the equivalent strata in the typical oil-shale districts, the only difference being in the quality of the shales, which here have no economic value. On the other hand, from the Houston Marl downwards to the Burdiehouse Limestone there is a sudden and remarkable departure from the normal.

It ought to be stated that the cores of the borings were carefully examined by a skilled borer, and at frequent intervals by the writer for the purposes of this report, with special reference to any possibility of faulting. No trace of faulting was detected anywhere below the Houston Marl. The Houston Coal and Grey Shale, poorly represented in No. 1 Bore, have almost disappeared in No. 2 Bore. The Fells Shale is totally absent, arenaceous sediments taking its place. The Broxburn Marls have disappeared except for a layer 5 in. thick of greenish colour and of the usual soapy texture; and, on the other hand, there is an exaggerated development of the "cement" bands usually found in the Marls: here they form thick limestones which occupy the larger part of the series. The Broxburn Shale is recognisable in No. 1 Bore and is 10 ft. thick. The oil-content is only 9 gallons per ton, but the oil is of high quality. The sulphate of ammonia amounts to 40 lbs. per ton. In No. 2 Bore the position is occupied by blaes, burnt by a small sill. In the first bore the Broxburn position is 35 fms. below the base of the Houston Marls, and only 30 fms. in the second bore.

The strata between the Broxburn position and the Burdiehouse Limestone show extreme attenuation, the distance being 49 fms. in No. 1 Bore, and only 29 fms. in No. 2 Bore, against over 100 fms. in the Philpstoun field. The solid sandstone some 10 fms. below the Broxburn position may be taken to be the Binney Sandstone, but there is no trace of the Dunnet Shale, nor is there room for the thick set of strata which normally would come below.

In No. 1 Bore a poor oil-shale 14 ft. thick rests on the top bed of the Burdiehouse Limestone, and would thus represent the Camps Shale. It underlies a light-brown entomostracan limestone about 12 ft. thick, which may possibly take the place of cement-ribs met with about that position in the Philpstoun field. In No. 2 Bore the poor oil-shale is replaced by black blaes, and the overlying limestone is absent.

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The Burdiehouse Limestone is of the usual type and of considerable thickness. In No. 1 Bore 3 fms. of blaes separate a top bed 42 ft. 6 in. thick from a lower bed in which the boring stopped.

To sum up, these two borings indicate, firstly, that the Blackness district does not contain reserves of oil-shale; secondly, that the sequence above the Houston Coal position is fully developed; and, thirdly, that the sequence between the Houston Coal and the Burdiehouse Limestone shows intense attenuation.

These points are brought out in the sections forming Fig. 3, two of which, namely, that of West Calder and that of Bridgend, are borrowed from the Geological Survey Memoir.

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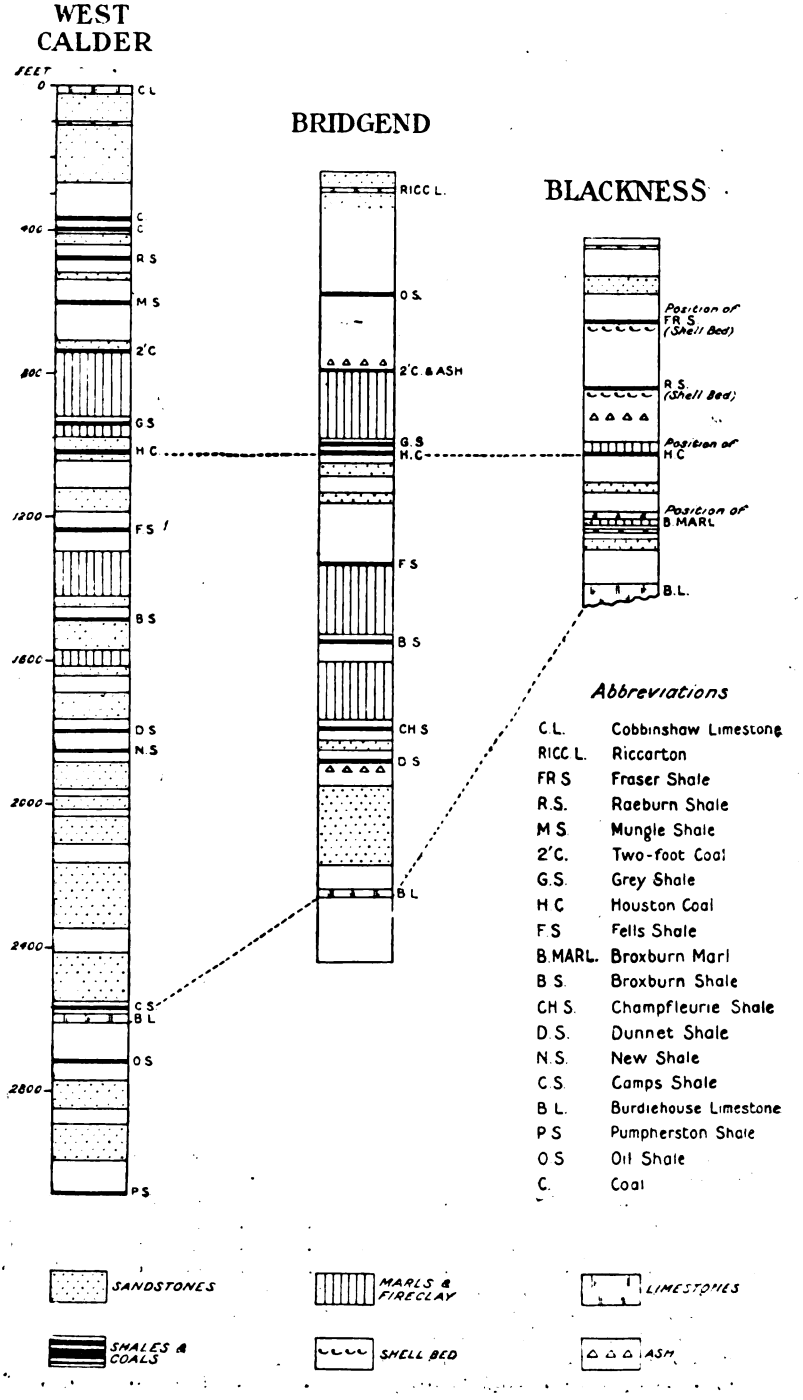
FIG. 3.—COMPARATIVE VERTICAL SECTIONS, SHOWING ATTENUATION OF THICKNESSES IN THE NORTH-WESTERN CORNER OF THE LOTHIAN OIL-SHALE FIELD.



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APPENDIX III.

Coventry Colliery.

By T. Eastwood.

The colliery is situated near Newland House Farm, Keresley, in the New Series One-inch Map 169, and the Six-inch, Warwick, 16 S.E.

There seems to be a widespread notion in the Midlands that workable coals terminate southwards on the latitude of the southern end of the South Staffordshire Coalfield. Recent explorations in Warwickshire prove that, at any rate near the prescribed boundary, workable seams of good quality are present. In the 'Summary of Progress for 1914' (*Mem. Geol. Surv.*) an account is given of two borings put down by the Warwickshire Coal Co., at Keresley and Whitmore Park. Since then the colliery shafts at Keresley have been completed, and, in view of possible future explorations to the south, it seems desirable to publish a description of the strata passed through. Up to November, 1915, the sinking to a depth of 730 ft. was visited periodically and the material examined. The war prevented further investigation until February, 1919, when sinking had been finished and roads had been driven out in the Thick Coal to two or three hundred yards from the shafts. A series of specimens that had been kept at the colliery were examined. These were not quite complete and of small size, but they served to identify the main sub-divisions. They showed that there are no sharp lines of demarcation between the various groups of strata, and that the Keele and the Corley beds are lithologically similar.

The shafts are 21½ ft. in diameter and 60 yards apart. No. 1, of which an abridged section is given below, is the southern shaft. It differs only in minor details from No. 2 Shaft.

No. 1 Shaft, Coventry colliery, Warwickshire Coal Company.

(Abridged from a section supplied by Mr. W. P. Evans, and notes in square brackets added to the original account.)

	Thickness. Ft.	In.	Depth. Ft.	In.
Upper Coal Measures:—				
Corley Beds—				
Red marls, sandy in part with occasional thin red and grey sandstones	98	5	98	5
Red sandstone and conglomerate [pellets of marl in a calcareous sandy matrix]	47	5	145	10
Red marls with thin sandstone bands	11	8	157	6
Hard red sandstone	20	6	178	0
Red marl	143	6	321	6
Red sandstone [purplish coarse sandstone with scattered pebbles] and conglomerate [dark-purplish sandstone-pebbles of Silurian age, and red and yellow cherts and white-grey limestone of Carboniferous age. Arley Exhall Conglomerate]	116	6	438	0

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	Thickness. Ft.	In.	Depth. Ft.	In.
Keele Beds—				
Red marl and red and grey marl	55	8	493	8
Red and grey sandstone very jointy; pebbly in lower part [pellet bed]	25	1	518	9
Red sandstones with thin marls	209	9	728	6
Alternating beds of red marl and sandy marl ...	57	0	785	6
Grey sandstone [? *Spirorbis Limestone* of Longford Tileries]...	1	0	786	6
Alternate red marls, sandy marls and sandstones ...	146	0	932	6
Red and blue marls, sandy marls and sandstones; a little grey conglomerate at base with coal streaks, *Stigmaria and Sigillaria*	270	9	1,203	3
Halesowen Series—				
Brown and blue marl	46	9	1,250	0
Blue marly conglomerate 3 ft. 9 in. blue limy sandstone 3 ft.; green blue limestone 2 ft. 9 in. [fine calcareous sandstone] blue limy sandstone 1 ft.	10	6	1,260	6
Brown and blue marls and shales	81	6	1,342	0
Bastard blue limestone with ironstone balls [fine calcareous sandstone [? Index Limestone]	3	6	1,345	6
Blue and brown marls and blue shales	93	6	1,439	0
Coal	0	10	1,439	10
Dark-blue shale with a little fireclay	23	8	1,463	6
Blue sandstone	56	6	1,520	0
Coal	0	4	1,520	4
Blue sandy shale with limestone-balls	43	8	1,564	0
Grey rock, flaggy in lower part	35	9	1,599	9
Coal, irregular contorted band	0	3	1,600	0
Dark fireclay and blue shales with ironstone-balls ...	19	0	1,619	0
Coal	1	0	1,620	0
Dark fireclay and blue shales with ironstone-balls ...	6	6	1,626	6
Coal and bass	0	6	1,627	0
Etruria Marls—				
Blue sandy fireclay and shale	11	0	1,638	0
Purple and yellow marl	7	0	1,645	0
Blue sandy shale 27 ft. 6 in., brown marl 1 ft. 3 in.; fine-grained blue sandstone 16 ft. 3 in., multicoloured sandy shale 1 ft. 9 in....	46	9	1,691	9
Blue sandstone with irregular bands and pockets of brown-grey conglomerate [Espley Rock] and brown and blue sandy shale	33	9	1,725	6
Blue, brown and yellow marl	22	0	1,747	6
Grey rock [Espley Rock] with shale and fireclay nodules	16	6	1,764	0
Yellow and brown fireclay and grey sandy shale ...	17	0	1,781	0
Middle Coal Measures:—				
Grey rock	47	0	1,828	0
Grey fireclays and shales with some ironstone ...	95	0	1,923	0
Coal	1	6	1,924	6
Grey shaly sandstone	45	0	1,969	6
Coal 2 ft. 5 in.; coal and dirt 9 in.; coal 1 ft. 9 in. [Four Feet Coal]	4	11	1,974	5
Grey sandy fireclays and shales with ironstone-balls [4 ft. 6 in. of black shale at 2,014 ft. may represent the ? "Marine horizon" of the boreholes]	118	3	2,092	8
Blue shale with ironstone-bands—"Ragged Stone" Ironstone Measures	18	9	2,111	5
Black shale	1	9	2,113	2
Thick Coal { Coal—Two Yard Coal	5	4		
Thick Coal { Holing dirt	0	4		
Thick Coal { Coal—Ryder and Ell Coals [no visible parting] ...	9	11		
Thick Coal { Holing dirt	0	1		
Thick Coal { Coal—Slate Coal	6	0	2,134	10

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	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Holing dirt	1	2	2,136	0
Coal—Lady Coal	1	8	2,137	8
Dark fireclay and grey sandy shales with ironstone-balls [White Ironstone Measures]	26	10	2,164	6
Coal—Seven Feet Coal	3	4	2,167	10
Brown and grey fireclay with ironstone-balls... ...	4	2	2,172	0

The belt of sandstones and conglomerate at 438 ft. may be matched perfectly with the exposures at Arley station, and at Exhall. Here, as elsewhere, they form a convenient base to the Corley Beds, though the rocks above and below them are of similar aspect.

In the Keele Beds the nodular Spirorbis limestone (probably equivalent to that of Maxstoke) found near the top of the series in the two borings was not recognised in the shafts, but the "grey sandstone" 1 ft. thick at a depth of 786 ft. in No. 1 probably represents the Spirorbis limestone that occurs about 400 ft. above the base of the Keele Beds at the brickpit by Longford station. It will be noticed that there is a greater development of sandstone above this horizon at the shafts than in the borings.

The Etruria Marls maintain the same thickness as near Nuneaton, but are mainly grey in colour, though a few thin beds of typical purple and mottled marls are present in addition to Espley Rocks.

The measures between the base of the Etruria Marls and the Thick Coal call for little remark.

The Thick Coal is said to be of good quality. The "Spires" (a rather dull compact coal of good quality) of the Ell seam are present as usual, and in places the Slate Coal takes on in part a "spiry" character with a small development of bastard cannel. The Ell and Ryder together vary from 10 to 11 ft. in thickness. The inferior coal known as the Bare Seam, which elsewhere occurs between the Two Yard and Ryder coals, appears to be absent, but the pea-like "Ryder stone" occurs in thin lenticles near the base of the upper seam.

Near the shaft the seam suffers from slight rolls, and is split in places by irregular partings of hard white micaceous sandstone a few inches in thickness, which have the appearance at first sight of intrusive white trap.

Water from fissures proved a serious obstacle to sinking. Down to 180 ft. the flow amounted to 500 gallons per minute. This was shut off by coffering. The sandstones and conglomerates at the base of the Corley beds yielded 2,600 gallons per minute in both shafts, and were shut off by cast-iron tubbing. On resuming sinking, water again proved troublesome, and the cementation-process for stopping the fissures was adopted with great success.

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APPENDIX IV.

Note on the Lower Greensand in the West Bilney Borehole, Norfolk.

By J. Pringle.

This borehole, made in 1918, is situated 4/5 of a mile south of West Bilney, about six miles south-east of Kings Lynn. It commenced in superficial deposits at an estimated height of about 20 ft. above O.D., and, after passing through the Lower Greensand, entered Kimmeridge Clay at the depth of 130½ ft. In a brief account of the latter formation published elsewhere,[1] the details of the Lower Greensand were not set forth: these are as follows:—

	Thickness.		Depth.	
	ft.	in.	ft.	in.
Superficial deposits	19	6	19	6
Light-brown and silvery sands	74	0	–	–
Blue sandy clay, not examined	0	6	–	–
Hard glauconitic sandstone with small brown phosphatic pebbles	0	4	–	–
Soft incoherent glauconitic sand	2	0	–	–
Brownish-green glauconitic sandstone with fragments of lignite	0	10	–	–
Dark-brown fine-grained glauconitic sand with small patches of white sand	5	0	–	–
Hard dark-brown glauconitic grit with irregular fragments of compact fine-grained brown sandstone ..	0	6	–	–
Soft dark-grey glauconitic sand with fragments of lignite	21	10	–	–
Grey sandy limestone with numerous small well-rounded black phosphatic nodules, some enclosing shell-fragments. Iron pyrites plentiful in matrix ...	2	0	–	–
Dark-brown fine-grained glauconitic sand	4	0	130	6
Kimmeridge Clay	153	8	284	2

The uppermost part of the section is based on the cores obtained from a second borehole situated a few feet away from the earlier hole. It is likely that the whole of the sands belong to the Sandringham Sands, which are said to be probably over 100 ft. thick.[2] There was no sign of the Snettisham Clay. According to the bore-record a hard grey sandy limestone, full of well-rounded black phosphatic nodules, was passed through 4 ft. above the base of the formation. This limestone is evidently a basement-bed, and its position as recorded may be due to an accidental reversal of the cores before the journal was made.

[1] 'Special Reports on the Mineral Resources of Great Britain,' *Mem. Geol. Surv.*, vol. vii, 2nd ed. (in the press), p. 37.

[2] 'The Geology of the Borders of the Wash,' *Mem. Geol. Surv.*, 1899, p. 5.

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APPENDIX V.

Glauconite-sand in Borings near Lewes, Sussex.

By Sir A. Strahan, K.B.E., etc.

A boring, recently been made by Messrs. Duke and Ockenden at Iford, near Lewes, started in alluvium, and after passing through a few feet of Lower Chalk, penetrated the Upper Greensand and Gault, the section as supplied by the borer being as follows:—

	Thickness. Ft.	Depth. Ft.
Marl and gravel	25	25
Rock and clay	11	36
Clay	289	325
Black sand	5	330
Sand	4	334

Water overflows at 180 gallons per hour. Rest level 21 ft. above surface. The height of the surface is about 30 or 35 ft. O.D.

The "black sand" at 330 ft. depth consists almost wholly (upwards of 99 per cent.) of grains of glauconite. The grains are of rounded or subangular outline, averaging 0·2 mm. in diameter and are loosely held together. This glauconite-sand, which appears to be unique in Britain, is being made the subject of further examination. It differs from the glauconitic rock of Ebbsfleet, described in the 'Summary of Progress' for 1911, pp. 72, 73, in the respect that the glauconite in that rock formed a cementing matrix in which quartz-grains were embedded.

A boring now in progress, midway between Plumpton and Plumpton Station and 5½ miles N.W. of Iford, has reached the same glauconite-bed under 130 ft. of Gault. The rock is not conspicuously granular, but appears to be made up to the extent of about 90 per cent. of glauconite in a finely divided state, with an admixture of rounded grains of quartz and some argillaceous material. It is 4 ft. thick.

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1920.

I.—INTRODUCTION.

By J. S. FLETT, M.A., D.Sc., LL.D., F.R.S.

During the year 1920 changes on the staff of the Geological Survey were exceptionally numerous and important. In July Sir Aubrey Strahan, Director, and Mr. G. W. Lamplugh, Assistant Director (for England and Wales), retired after completing their service; Dr. Flett (Assistant Director for Scotland) was appointed Director, and Mr. J. Allen Howe (Curator of the Museum) became Assistant Director in Mr. Lamplugh's place. Dr. Walcot Gibson was promoted Assistant Director for Scotland in succession to Dr. Flett, and proceeded to Edinburgh in November. Dr. McLintock, of the Royal Scottish Museum, formerly a member of the staff of the Museum of Practical Geology, was appointed to succeed Mr. Allen Howe as Curator, but did not take up his duties before the close of the year. The staff was expanded by the appointment of six geologists, and Mr. Henry Dewey and Mr. Bernard Smith were appointed District Geologists.

It was decided to begin the revision of the maps of some of the more important districts of the North of England, and to open local offices in Newcastle-upon-Tyne and in Whitehaven. Mr. R. G. Carruthers is to take charge of a field-unit, comprising four geologists, in the Northumberland and Durham district, and Mr. Bernard Smith is to superintend the work of a similar unit in Cumberland and Westmorland. By the close of the year a start had been made in the work of organising these new field-units.

In England and Wales during 1920 work was continued in all the districts in which mapping had been in progress before the war, viz., the London district under Mr. R. G. Carruthers, the Warwickshire and Staffordshire district under Dr. Walcot Gibson, and in Shropshire under Mr. T. C. Cantrill. At the same time it

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was necessary to continue the investigation of the country's resources of economic minerals, which had been in progress during the previous six years, in order to complete the series of Special Reports on the Mineral Resources of Great Britain, inaugurated by Sir Aubrey Strahan, which had proved so successful. Of these the principal were a series of reports on the lead and zinc ores of England and Wales, on copper ores, and on salt deposits. At the close of the year these reports had been completed in manuscript, and were in the press or being edited for publication. Several reports on iron ores, arsenic, fireclays and siliceous refractories were published during 1920, and new editions of the reports on silica rocks and on cannel coal, mineral oil, etc., in England were issued. In all these cases a certain amount of field-work had to be done to bring the information up to date.

In Scotland field-work was continued in all the districts which were in hand before the War, viz., Ayrshire, the Central coalfield (with Clackmannanshire), Mull and the adjacent islands, and Sutherlandshire, but part of the time of the staff during the summer was taken up with special enquiries. Mr. Wilson has prepared a report on the lead, zinc and copper ores of Scotland, which involved much field-work. Dr. Lee has begun a revision of the Secondary rocks of the Brora coalfield, with especial reference to the correct determination of the palæontological zones. Mr. Macgregor has edited a report on the iron ores of Scotland, which was published during the year.

In the London district Mr. Carruthers and his staff have been at work principally in the Lea Valley, and near Crayford and Erith on the south side of the Thames. Several points of interest have been added to the information available. The Reading Beds of Collier's End show great lateral variation, which may indicate that they are unconformably overlapped by the London Clay. Near Swanscombe the Blackheath Beds are exceedingly thin, and may, indeed, be absent in places; but near Shorne they have a thickness of about 20 ft., and are apparently of normal character. The terraces of the Lea Valley have been the subject of careful study.

The Swanscombe gravels, which yield many palæolithic flint implements, are divisible into a 100-ft. terrace, and the 50-ft. deposits, of which the latter apparently form a continuous series down to the bottom of the buried channel of the Thames.

In the Midlands district (Warwickshire and Staffordshire) the solid rocks surveyed are Cambrian, Silurian, Carboniferous and New Red. A small area of the quartzite of the Lickey Hills, near Rubery, enters the Birmingham Sheet, but it has not been proved to contain fossils, and is presumptively of Lower Cambrian age. Of the Silurian rocks of this district the Upper Llandovery is represented by a fossiliferous sandstone near Rubery village. The Wenlock strata which follow, especially those of the Wren's Nest, Dudley, are well known to all geologists. They comprise the Wenlock Shales and Limestone, long quarried and now

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mined. Above these the Ludlow Shales and the higher Silurian up to the horizon of the Ledbury Passage Beds have a fairly extensive development within the area surveyed during the year, especially around Turner's Hill and Ellowes Park. The Upper Carboniferous of the Dudley district comprises the Etruria Marls, the Keele Beds and the Hamstead Beds, of which the last-named contains a limestone-breccia, or calcareous conglomerate. Near Halesowen the Halesowen Sandstone contains Spirorbis limestones and three seams of coal which are not workable. The Keele Beds and Hamstead Beds, which occupy the top of the Carboniferous succession, are very typically developed, and seem to be quite conformable throughout.

The Bunter and Keuper of Newport (Salop) present some features in common, but are, on the whole, well-characterised and distinct. An unconformability probably occurs between them, but its significance is at present impossible to estimate. In the Birmingham area the Upper Mottled Sandstone assumes great importance, and has served as a source for moulding sands, which are of high reputation.

The Glacial deposits of the Midlands in the vicinity of Newport and Birmingham, though they have been very minutely investigated by many local geologists, continue to furnish results which are of great interest as a record of the closing stages of the Glacial period. Around Newport sands and gravels were deposited as series of fans, the different series marking successive positions of the ice-front. Apparently there are no terminal moraines. Eskers trending at right-angles to the ice-front connect corresponding fans in the several series. At a later stage an extensive lake covered the area up to the 300-ft. contour. Its shore-line is shown in places by terraces, but as a rule merely by a notch.

Although systematic mapping has not yet been begun in the Whitehaven district, Mr. Smith has had opportunity of examining the cores of certain bores that have recently been made. He finds that these indicate a remarkable change in the character of the Carboniferous Limestone in the vicinity of the boundary fault of the exposed Whitehaven coalfield. This was not wholly unexpected, as the surface indications had suggested a similar conclusion; but it is evident that when the mapping has demonstrated the conditions in the exposed coalfield, and further boring has taken place, important results may be anticipated.

In Scotland the field-staff were engaged during most of the summer in the primary 6-in. survey of the Highlands. New light has been thrown on the geology of Iona by Mr. Anderson, who finds that the island consists of a platform of Lewisian Gneiss overlain by Torridon sediments. In the Lewisian there are rocks of igneous, and others of sedimentary origin; among the latter are the well-known Iona marble and dark graphitic schists. Intrusive masses of epidiorite and pegmatite traverse the gneisses and schists. The basal conglomerate of the Torridon is, in

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places, intensely crushed, but the common boundary of the two series is not regarded as a thrust-plane. Dykes of basalt and lamprophyre intersect the Torridon strata, and the Newer Granite of the Ross of Mull possibly produces contact alteration in these sediments.

A very interesting section at Gribun, in the Island of Mull, has now been investigated for the first time since Professor Judd described it in 1878. Many fossils have been collected, and have been determined by Dr. Lee. Trias and Rhaetic rocks form the basement, the latter yielding characteristic fossils. Broadford Beds follow (Hettangian and Sinemurian) containing well-preserved fossils, and Cretaceous rocks, including Cenomanian (Greensand). The whole sequence is interesting as affording one of the most important exposures of Secondary rocks in the island of Mull. In Ardnamurchan Mr. Richey has found a considerable outlier which is probably Inferior Oolite though it has a resemblance to Chalk.

The mapping of Mull has been completed, and the reports describe the usual variety of lavas and basic intrusions, with additional information on the Secondary rocks that underlie the volcanic plateau, and the Tertiary sediments among the lavas. The famous fossil tree of Burgh, which has been known for over a hundred years, has been very carefully described, and specimens of the fossil wood sliced for microscopic examination. Ardnamurchan, which is part of a Tertiary volcano of the same age as the mountains of Skye and Mull, has been visited by Mr. Richey, but the actual survey of the ground has hardly been begun. Staffa, famous for its basaltic pillars and caves, consists mainly of a single lava with its slaggy top covered by a thin layer of ash. One small, intrusive sill with clearly transgressive margins occurs below the base of the lava.

In Easter Ross the area surveyed consisted mainly of typical Moine gneisses intersected by lamprophyre dykes, and in the adjacent parts of Sutherland there are also granitic intrusions with allied basic masses which occasionally give rise to rocks of hybrid origin.

The igneous rocks which form the uplands around the North Ayrshire coalfield have been shown to include an extensive development of trachytic lavas overlain by basalts of Dalmeny type. These trachyte lavas may occur in two series, and are of interest because most of the trachytes of the West of Scotland have hitherto been believed to be of intrusive origin.

In Stirlingshire Mr. Dinham has brought to light an encrinital limestone which provides an important landmark in the correlation of the Carboniferous Limestones of Campsie with those of the Bannockburn district.

The Alloa coalfield of Clackmannanshire forms a link between the Central coalfield and that of West Fife. The revision is now in hand, and it is considered open to question whether the Barren Red Measures of the Upper Carboniferous occur in this area, as has hitherto been supposed.

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Extensive mining developments are taking place in the Douglas coalfield, and much new information is being collected especially from bores in progress. The revision of this district is proving of great interest, and resulting in a much more correct interpretation of the complicated structure of this coalfield.

Dr. H. H. Thomas has made an investigation into the petrographical characters of the foreign stones that compose the inner circle at Stonehenge, and arrives at the conclusion that they have been transported by human agency from Prescelly Mountains in Pembrokeshire, no doubt expressly for the purpose. This seems to set at rest a question which has long interested the antiquarian, and sheds an interesting light on the importance in which the building of Stonehenge was held by the early races of Britain.

II.—FIELD WORK.

(A)—ENGLAND AND WALES.

1. London and South-Eastern District.

H. Dewey, District Geologist.
R. L. Sherlock, D.Sc., A.R.C.S.
C. E. N. Bromehead, B.A.
R. W. Pocock, B.Sc.
T. Robertson, B.Sc.
} Geologists.

In the London District the mapping, which was suspended during the war, has been continued in an easterly direction on both sides of the Thames. On the southern side, Mr. Bromehead has surveyed the ground in Sheet 271 (Dartford) extending from Erith and Crayford to the margin of the map a mile or two east of Gravesend.

Dr. Sherlock has mapped in Sheet 239 (Hertford) the area extending eastwards from Hertford to Ware and thence down the Lea Valley to Cheshunt, and a small area in Sheet 221 (Hitchin) between Woodhall Park and Sacombe. Mr. Pocock and Mr. Robertson were engaged for a few weeks mapping the ground around Goff's Oak, Northaw and Cheshunt. Some parts of the North London map (Sheet 256) have been revised by Mr. Bromehead, especially the districts of Hampstead, Holloway, Stoke Newington, Bow, and West Ham, while Mr. Pocock has revised those of Watford, Bushey and Stanmore. The work was under the superintendence of Mr. Carruthers until his transference to Northumberland in October, when it was placed in the charge of Mr. Dewey.

CRETACEOUS.

The Chalk bordering the Thames between Erith and Gravesend has been mapped by Mr. Bromehead. It all belongs to the zone

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of *Micraster coranguinum*, as previously ascertained by Mr. Dibley.[1]

TERTIARY.

Dr. Sherlock records a section of abnormal Reading Beds at the south of Collier's End village (Sheet 221) in a disused brickyard. Below 8 ft. of lead-grey clay with brown mottling, which appears to be London Clay, there is a sharp plane of division. In downward succession it is followed by 3 ft. of black, somewhat silty clay, mostly stoneless, but with occasional flint-pebbles, some of which stand vertically. Most of the pebbles are black but some are yellow and others red, and a few are fragmentary. The black clay is local, being absent from a pit only 200 yds. to the west. The black bed passes down quickly, but with a sharp dividing plane, into 8 ft. of greenish-grey, sandy clay with indefinite crimson patches, which contains a few calcareous nodules. Below the clay is a stony mass of flints and flint pebbles resting on a piped surface of chalk, with the usual black or green-coated flints at the junction. Less than a mile to the east there is a 12-ft. pit in the typical fine white sand of the Reading Beds. These sections seem to indicate a rapid lateral change in the Reading Beds and an unconformable overlap by the London Clay, not previously noted in this part of the London Basin.

From Hertford to Great Amwell the Tertiary escarpment follows the right bank of the Lea, but to a great extent is buried under Drift deposits. Reading Beds, however, are visible in a pit situated in the small valley that extends from the east end of Hertford to Little Amwell. Here an 8-ft. section shows lilac silty clay, passing down into white sand with glauconite. At a higher level, behind Fox Hole Farm, an obscured brickyard appears to be in the London Clay. Across the gorge of the Lea, at Great Amwell, the Tertiary escarpment continues along the south side of the Ash, but here also it is buried under Drift.

At Great Amwell the Lea, having breached the escarpment, turns southwards and flows over the dip-slope of the Tertiaries. London Clay covers some square miles to the west of Broxbourne and Cheshunt and is mostly under plantations. On the east side of the Lea opposite Hoddesdon and Cheshunt there is a strip of bare London Clay between the river flat and the cap of boulder clay, but no sections exist on either side of the river.

In the area surveyed by Mr. Bromehead, the Thanet Sand and Woolwich Beds maintain their usual characters, but it is noticeable that Messrs. Priest and Stamp have detected fossils in the Bottom Bed near Swanscombe.[2] The same authors have described the Blackheath Beds of the Swanscombe outlier.

[1] 'Notes on the Chalk of the Medway Valley, Gravesend, etc.,' *Proc. Geol. Assoc.*, vol. xxix, 1918, pp. 68–105.

[2] 'Geology of Swanscombe Eocene Outlier,' *Proc. Geol. Assoc.*, vol. xxxi, 1920, pp. 187–199.

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These beds are so attenuated in this district that they were not indicated on the original 1-in. map. Even in the present 6-in. survey it has not been found possible to detect them everywhere; for example, on the west side of Swanscombe Wood the London Clay is shown as resting directly on Woolwich Beds. In the next large Tertiary outlier to the east, that of Shorne and Cobham, the Blackheath Beds reappear in force, at least 20 ft. of pebble beds and a few feet of sand being visible in sections. Here, therefore, this division has a development similar to that in the type area of Blackheath and Bexley. No cause has yet been suggested to account for its great attenuation in the intermediate area. The London Clay is the highest Tertiary formation in the district.

PLEISTOCENE.

In the area mapped by Dr. Sherlock the Chalky Boulder Clay with accompanying fluvioglacial sand and gravel covers most of the high ground. However, north of the Lea the Chalk rises to the surface between Woodhall Park and Sacombe, and the usually continuous sheet of drift is reduced to patches on the hill tops. The sand and gravel as a rule underlies the boulder clay and generally crops out in the slopes of the valleys, while boulder clay covers the plateau; but as the sand and gravel is in thick lenticles, it is absent in some parts and in others so thick that it extends on to the plateau. A large pit, south-east of Hertford, shows 5½ ft. of sand and gravel on 16 ft. of Chalky Boulder Clay, and below this about 14 ft. of sand and gravel resting on chalk. Here there is gravel above as well as below the boulder clay, and it seems probable that the clay is not the main mass, but a discontinuous band that appears sometimes below and sometimes within the gravel, as at Hertingfordbury, Watton-at-Stone, and the Ware section previously described.[1]

The fluvioglacial sand and gravel borders the Lea Valley on the western slopes from Hoddesdon to Cheshunt, and its level falls with the valley. South of the Lea, areas of clay with pockets of gravel are found on the top of the plateau at Little Amwell. They are characterised by the absence of the far-travelled pebbles, so common in the fluvioglacial gravels, and are composed mainly of flint-pebbles derived from Tertiary deposits. They contain also pebbles of white quartz and, occasionally, of Lower Greensand chert, both constituents being probably of Tertiary origin. With the gradual fall of the surface southwards the patches of clayey gravel become partially overlain by boulder clay, but they are always relatively higher than the adjacent fluvioglacial sand and gravel.

In the Lea Valley a terrace appears at Great Amwell. The northern boundary makes a feature extending across the valley and covered by fluvioglacial gravel probably marks a Reading

[1] 'Summary of Progress for 1914' (*Mem. Geol. Surv.*), 1915, p. 31. Nos. 1 and 3 in the section there given are identical.

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Beds feature. The terrace has been followed along the west bank of the Lea southwards as far as Cheshunt. Excavations in its sand and gravel show sections identical with those in the fluvioglacial deposits. The difference between them is firstly, position; and secondly, as recorded at Hoddesdon by Mr. S. H. Warren,[1] the presence in the terrace gravel of flint implements. Brickearth covers parts of the terrace and has yielded bones of mammoth, reindeer and some other animals, and flint implements. It seems probable that the terrace may prove to be of Taplow age.

At Cheshunt small areas of blue and black clay are recorded by the nurserymen where one would expect gravel. So far no sections are available, but it is not unlikely that the clay is contemporaneous with the Arctic Bed found by Mr. Warren[2] at Ponder's End, lower down the Lea.

Mr. Bromehead finds that round Darenth Wood and Swanscombe Park there are patches of "Plateau" gravel. These consist of materials derived locally and from the south, and differ markedly from the gravel of Shooter's Hill, for which a Pliocene age has recently been claimed.[3]

The river-deposits of the Swanscombe neighbourhood had been carefully investigated by Messrs. R. Smith and H. Dewey previous to the survey.[4]

Although on the Essex side of the Thames the usual three terraces can be detected and were mapped by Mr. T. I. Pocock 18 years ago, on the south side there appears to be a continuous deposit from about the 50-ft. level to the bottom of the buried channel. This deposit is best known in the Crayford-Erith area, where many deep sections have been available for study. It will probably be found advisable to designate the river-gravels of the Dartford Sheet as the "Swanscombe" and the "Crayford" terraces, the former being equivalent to the Boyn or 100-ft., and the latter to the Taplow or 50-ft., and the Flood-plain terraces.

Besides the bedded river-gravels and brickearths, there are tumultuous deposits, found in several of the valleys tributary to the Thames, consisting of chalk-rubble, gravel and brickearth. These were evidently formed at a time when the topography was approximately that of the present day, since they occur along existing stream-valleys and depend for their composition on the strata bordering the valleys. Where Chalk crops out they consist of a rubble of chalk fragments, sometimes re-cemented, to which the term Coombe Rock has been applied; in the neighbourhood of Tertiary outliers they are brickearths

[1] *Quart. Journ. Geol. Soc.*, vol. lxviii, 1912, p. 225.

[2] *Op. cit.*, pp. 213–217.

[3] Leach, A. L., 'Supplementary Notes on Geology of Shooter's Hill,' *Proc. Geol. Assoc.*, vol. xxxi, 1920, pp. 127–132.

[4] *Archæologia*, vol. lxiv, 1913, pp. 177–204; vol. lxv, 1914, pp. 187–212.

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formed of re-sorted Tertiary material and with difficulty distinguished from those beds *in situ*; where patches of Swanscombe Terrace gravels occupy the high ground they are essentially gravels. The varieties of composition are so intermingled that it is impossible to map them separately, and it is proposed to include them under the term "Coombe Deposits." From the contained fossils and implements and from the manner of accumulation the period of formation appears to be the end of the Taplow stage, when the semi-arctic conditions of the Mousterian culture prevailed.

ECONOMICS.

The chief industry of geological importance is the manufacture of Portland cement. Along the river-bank from Stone to Gravesend chalk quarries for this purpose are almost continuous, and the operating companies are being forced to obtain their chalk from localities further and further inland. The Associated Portland Cement Manufacturers are also working the London Clay of Swanscombe Wood in a huge pit; the clay is made into slurry on the spot and piped to the works.

The Erith moulding sand (Thanet Sand) was worked extensively during the war, and the industry is still of great importance.

The Swanscombe Terrace gravels are largely dug for concrete-making and other purposes.

Over much of the area the Bottom Bed of the Woolwich Series is strongly impregnated with iron-oxide. There are some indications of an ancient "bloomery" working this ore in Lord's Wood, Green Street Green.

2. Warwickshire and Staffordshire District.

W. Gibson, D.Sc., District Geologist.
E. E. L. Dixon, B.Sc., A.R.C.S.
T. Eastwood, A.R.C.S.
T. H. Whitehead, B.Sc., A.R.C.S.
T. Robertson, B.Sc.
} Geologists.

During the past season, work in the Stafford Sheet (139) and in the north-western part of the Wolverhampton Sheet (153) has been continued by Messrs. Dixon and Robertson in the neighbourhood of Newport, Stone and Stafford. In the Dudley Sheet (167) Mr. Whitehead has mapped part of the mining district and its western border, lying between Tipton, Cradley and Kingswinford; while in the Birmingham Sheet (168) Mr. Eastwood has surveyed the south-western suburbs of that city and the ground extending westward towards Halesowen.

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CAMBRIAN.

The oldest rocks in the district examined by Mr. Eastwood are the Cambrian quartzites of the Lickey Hills, the northern portion of which falls, at Rubery, within the Birmingham Sheet. The mass consists of quartzite, similar to that of Hartshill, near Nuneaton. The beds strike approximately north-and-south, *i.e.*, parallel to the ridge, though the dip is very inconstant. Neither the top nor the bottom of the quartzite is exposed, and so far the quartzite has yielded no fossils; but on lithological grounds the Lickey Quartzite is regarded as of Lower Cambrian age and equivalent to the Park Hill and Tuttle Hill series of Warwickshire.

SILURIAN.

The Lickey Quartzite is succeeded unconformably by sandstones, varying from a grey-white compact rock, very like the underlying quartzite in appearance, to open-textured reddish sandstone, occasionally calcareous. The basal bed frequently contains boulders and pebbles of the underlying quartzite, as may be seen in the quarries on the south side of the main road in Rubery village. Casts of fossils are fairly abundant, and establish the age of the sandstones as Upper Llandovery. Up to the present, Tarannon Shales have not been found in this area, and the Llandovery Sandstone appears to be succeeded at once by shales, clays, and mudstones, with thin bands of limestone, and by compact sandstone, all referable to the Barr or Woolhope Beds of the Wenlock. The only section in them is that afforded by Callow Brook, the stream in the Asylum grounds at Rubery, where they pass beneath the Halesowen Beds of the Upper Coal Measures.

The outcrops of Silurian rocks at the Castle Hill and at the Wren's Nest, Dudley, and at Turner's Hill near Sedgley (Sheet 167) have been surveyed by Mr. Whitehead. Of these, the lowest beds occur in the cores of the Castle Hill and Wren's Nest domes, and consist of Wenlock Shales. These are followed by the well-known Wenlock or Dudley Limestone, which consists of two bands separated by flaggy and nodular limestones and mudstones. Both these bands have been almost completely quarried away at the outcrop, though mining for the limestone still continues. The Lower Ludlow Shales, consisting of mudstones with bands and nodules of limestone, succeed the Wenlock Limestones. At Dudley the area occupied by the outcrop of these beds has been found to extend farther south than is represented on the geological maps hitherto published. They occupy the surface in the allotments south-west of the Priory, near the Grammar School, and in the grave-yard of St. James's Church, Eve Hill. In an exposure in a ditch to the west of the Grammar School playing-field the dip is south-west, whilst to the east of the playing-field it is east or a little south of

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east, indicating an approach to the southern termination of the Wren's Nest dome.

Mr. John Hughes has supplied details of a shaft and bore-hole sunk within the site now occupied by the Dudley Union Workhouse. The following is an abstract of the section :—

	Ft.	in.
Measures to top of Fireclay Coal - -	54	4
Fireclay Coal - - - - - - -	2	0
Rock, batt, clod, etc. - - - -	24	9
Bottom Coal (four coals with partings) -	10	0
Fireclays, binds, rock, etc. - - -	57	6
Mottled ground - - - - -	3	6
Red ground } Borehole - - -	4	6
Red rock } Borehole - - -	5	6
Red parting } Borehole - - -	0	6
	162	7

It is possible that the mottled and red measures at the base of the section may be Ledbury Passage-Beds. If this is the case, the Aymestry Limestone must lie at no great distance from the surface between the Workhouse and the Wren's Nest. This section may be compared with that of the Trial Pits at Shaver's End, referred to by J. B. Jukes,[1] where 68 ft. of measures were found between the Bottom Coal and a blue clunch believed to be the top of the Silurian.

At Turner's Hill and Ellowes Park the following beds are exposed :—

6. Ledbury Passage-Beds.
5. Temeside Shales.
4. Downton Castle Sandstones.
3. Upper Ludlow Shales.
2. Aymestry Limestone.
1. Lower Ludlow Shales.

Of (1) only a small portion is poorly exposed in a little quarry on the west side of Turner's Hill. The Aymestry Limestone (2) is exposed in the same quarry, and contains the characteristic fossil, *Conchidium knighti*, represented by small individuals. The outcrop of the limestone extends only a few yards to north and south of the quarry, being truncated in both directions by faults. Both (3) and (4) are poorly exposed in the western scarp slope and near the summit of the hill; whilst (5) was recognised from the fragments ploughed up in a field immediately to the south-east of Turner's Hill Wood. A bed believed to be one of the Temeside Bone-Beds was found in place in the ditch forming the southern boundary of this field. In the adjoining field to the south large fragments of highly micaceous, purple

[1] 'The South Staffordshire Coal-Field' (*Mem. Geol. Surv.*), ed. 2, 1859, p. 83; also *Vert. Sect.*, Sheet 18, No. 36.

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and green sandstones belonging to the Ledbury Passage-Beds (6) were found, thrown up by the plough. The Passage-Beds crop out in Ellowes Park also, and are well exposed in an east-and-west stream-course near Ellowes Park Farm.[1]

CARBONIFEROUS: COAL MEASURES.

Near Dudley, on the western margin of the South Staffordshire coalfield, the delimitation of the outcrops of the Middle Coal Measures, and of the various members of the Upper Coal Measures, has been continued by Mr. Whitehead.

The Etruria (Old Hill) Marls occupy the higher ground around Brierley Hill and Scott's Green, and are brought in by the Brierley Hill fault-trough. They also extend northward along the western margin of the exposed coalfield from the junction of the Brockmoor and Western Boundary faults at Brettell Lane nearly to Straits Green, the boundary of their outcrop to the east being determined largely by the Brockmoor and Shut End Faults. In general the Etruria Marls of this part of the coalfield appear sandier, and the marls of a duller purple colour, than around Old Hill and Oldbury.

The Halesowen Beds are nowhere preserved in the area surveyed, with the possible exception of some coarse greenish sandstones exposed in the brook north of Conqueror's Farm, Straits Green. If, as their characters suggest, these beds belong to the Halesowen group, they must be bounded on all sides by faults, as they abut, on the west against the upper portion of the Keele Beds, and on the east against the Middle Coal Measures.

The Keele Beds occupy the eastern half of Himley Park, and near the Straits form a shelf-like feature between the high ground formed of the Hamstead Beds to the north-west and the Western Boundary Fault to the south-east. They consist chiefly of red marls and sandstones, a 'pellety sandstone' or limestone breccia (conglomeratic cornstone) occurring in the cutting of the mineral railway in Himley Wood. There are at present insufficient data to determine what proportion of the Keele group is present at the outcrop in this area, or to establish the local thickness of the group.

Hamstead Beds.—These beds,[2] consisting of a lower Calcareous Conglomerate Group and a higher Breccia Group, occupy a strip of ground extending from near Kingswinford to Brettell Lane. The outcrop is bounded on the east by the Western Boundary Fault, and is separated from the Trias on the west by another fault. Only one band of calcareous conglomerate is recognisable, of which exposures occur north of Bromley Lane and near Buckpool. Another area of the Calcareous Conglomerate Group, with three conglomeratic horizons, comes in

[1] W. W. King, *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xiv, pt. 2, 1917, p. 92.

[2] W. W. King, *Quart. Journ. Geol. Soc.*, vol. lv, 1899, pp. 112–115.

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above the Keele Beds near the Straits, and the examination of these, together with the overlying Breccia Group, has been begun around Baggeridge and Gospel End.

North of Halesowen, in ground mapped by Mr. Eastwood, a small tract of highly-inclined Middle Coal Measures, including members of the Thick Coal, with the Gubbin Ironstone and the Heathen Coal, is being worked by a day-hole at Cockshot Lane, south-west of Blackheath. The ground is obscured by drift, and apart from the small coal-workings there are no exposures, though it is evident, since the Halesowen Beds come on east of Cockshot Lane, that a fault, described by Jukes as the Russell's Hall Fault, must intervene, as shown on the old 1-in. map (62 S.W.). The succession as far west as the Dudley canal is regarded as normal—the strata exposed at Coombes Wood Tube Works are believed to belong to the base of the Etruria Marls—though another fault, with a westward downthrow, may come in beyond, introducing beds half-way up in the Etruria Marls.

South of Halesowen there has been no exploration in the concealed coalfield since the Manor Pit was abandoned many years ago. The coals are believed to deteriorate rapidly in a southward direction.

The Etruria Marls call for little comment. Beds high in the succession are exposed in the brick-pits north-east of Halesowen station, where they consist of the usual dull-red marls and conglomerates (espley rocks), with occasional thin bands of coal. Good sections in espley rocks may be seen on Mucklow Hill, where the Russell's Hall Fault brings them against the Halesowen Sandstones.

The Halesowen Sandstones consist of sandstones interbedded with clays and shales, including thin seams of coal and at least two bands of Spirorbis limestone. When fresh, their prevalent colour is grey, though the sandstones usually weather buff or brown and are occasionally stained red, while the argillaceous beds range from white to almost black. The beds are sometimes olive- and chocolate-coloured, especially at the base and near the top of the group. The sandstones are occasionally both pellety and pebbly; the latter condition is especially marked in the basal sandstone, which in places so closely resembles an espley rock of the Etruria Marls that it is difficult to distinguish between the two groups.

The Spirorbis limestones of this group are grey or dirty white in colour, in contrast with the blue and blue-grey limestones of the overlying Keele Beds. The lowest limestone in the Halesowen area was at one time worked about 400 yds. east of Manor Farm, and apparently occurs as a flaggy band, 8 ins. to 1 ft. in thickness, immediately above a bed of sandstone. The same band is represented by debris on a dump from an air-shaft to the canal-tunnel at Lapal House, Moor Street. Its position in the Halesowen group is about 100 ft. above the base. During the excavation of the sewers for some new houses between Hayley Green

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and Hasbury (south-west of Halesowen) a similar bed was encountered. There *Spirorbis pusillus* was abundant and of unusually large size. In addition to the characteristic fossil, spines and scales of a fish of Acanthoid type are present, along with fragments of coal.

Higher in the succession, and probably not more than 150 ft. below the top of the Halesowen group, is another Spirorbis horizon. This may be seen *in situ* in a little tributary 300 yds. south of Illey Mill. The limestone is an 8-in. band of compact rock lying in a thin belt of clays between two sandstones, the lower of which is exposed in the brook by Illey Mill. Although the rock as a whole is compact, it is frequently made up of fragments of white limestone set in a matrix of grey limestone of equal hardness. *Spirorbis* is not abundant, but it occurs in both matrix and fragments. The locality mentioned above was first discovered by Dr. W. Gibson, and was afterwards described by the late Prof. Lapworth. During the past season, pits yielding fragments of similar limestone have been discovered between Illey Brook Farm and Illey Hall Farm. What is believed to be the same bed occurs in place in a ditch 200 yds. north-east of Warstone Farm near Lower Illey.

Several seams of coal occur in the Halesowen group, but as a rule they are very thin and impersistent. Attempts to work one or other of them have been made at the northern end of Offmoor Wood (Sheet 167); also near Rubery, and at California, but without success.

Sections in various portions of the sequence may be seen in the streams flowing northwards near Halesowen; but east of that town much of the ground is obscured by drift. Near Rubery, intermittent sections showing sandstones, clays, and coal, may be seen in the stream at Balaam's Wood, and in Callow Brook in the Asylum grounds. Recent excavations at the north end of the Asylum (Rubery Hill) exposed a seam of coal about a foot thick, associated with grey clay containing small fragments of fossil wood, and dipping westward off the Llandovery Sandstone.

The red rocks succeeding the Halesowen Sandstones and unconformably overlain by the Trias were originally classed as 'Permian of Salopian type.' In the South Staffordshire district, as in other areas in the Midlands, it is becoming increasingly clear that the whole of these beds must be relegated to the Carboniferous System. They consist of argillaceous and arenaceous sediments in which red is the prevailing colour, and the lower portion is characterised by occasional bands of bluish Spirorbis limestone. It is to this group that the name Keele Beds is applied.

The junction of the Keele Beds with the Halesowen Sandstones appears to be conformable, and the base is frequently marked by sandstones of dark lavender tint, such as are seen in Breach Dingle, near Romsley. These are succeeded by red

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marls and sandstones with thin bands of bluish limestone containing occasional specimens of *Spirorbis*. The band found by Mr. Cantrill[1] near Wassel Grove and believed to be about 50 ft. above the base of the group has not been located in the Romsley area. Another band, about 350 ft. above the base of the group, first discovered by Mr. Cantrill (*op. cit.*) near Offmoor Wood, may be seen in a fragmentary condition in a gully 200 yds. north-east of St. Kenelm's Hall, and in Breach Dingle at a point 400 yds. north-north-east of St. Kenelm's Rectory, while it is abundantly represented in the debris from the pipe-line of the Birmingham aqueduct (Elan supply) at the south-east corner of Offmoor Wood. What is possibly the same band has been recorded at Frankley reservoir, and it has since been seen in Egghill Dingle, Long Kettles Wood, near Gannow Green, at Hollymoor Asylum, and near Bartley Green.

Hamstead Beds.—Higher in the succession, the marls occasionally take on an even brighter red tint than usual, whereas the sandstones, although often red, are frequently brown or yellowish. In addition to change of colour these sandstones locally become markedly calcareous and highly charged with small rolled pellets of inorganic limestone, in addition to which occasional small fragments of organic limestone, calcareous mudstone, and other foreign matters occur. In the past these conglomeratic 'cornstones' were burnt for lime. Though similar rocks are found in the Keele Beds below, the position and general characters of the main belt of these calcareous sandstones link them up with the limestone conglomerates of the Hamstead Beds, found farther north at about the same position in the sequence.

Though the Hamstead Beds, which occupy an intermediate position between the Keele Beds and the trappoid breccia of the Clent Hills, are well exposed in natural sections near Romsley, they make much more striking features around Frankley, where they are surmounted by a capping of breccia—the outlier of Frankley Beeches.

The Clent Breccia has been so well described by Mr. Wickham King[2] that there is little to add here. Up to the present the evidence is in favour of general concordance between the breccia and the beds below, while the relation between it and the overlying Trias is one of marked unconformity.

Though giving rise to prominent features, it is, as a rule, not well exposed, especially in the main mass forming the high ground extending from the Clent Hills to Rubery. In the detached areas good road-sections are to be seen at Merritt's Hill near Northfield, and in the Halesowen-Birmingham road east of Quinton. In addition to the localities already known, a small outlier of the breccia has been found north-west of Bromwich

[1] *Geol. Mag.*, 1909, p. 449.
[2] *Quart. Journ. Geol. Soc.*, vol. lv, 1899, p. 97.

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Wood, between Frankley and Bartley Green. It is about 400 yds. in length by 200 yds. in breadth, and probably does not exceed 20 ft. in thickness. Though there are no sections in it, the ditches and the debris on the ploughed fields afford ample evidence of the presence of breccia.

TRIAS.

In the district of Newport (Salop) Mr. Dixon finds that, as elsewhere, the several lithological types on which the original classification of the Trias was based are not rigidly confined to the subdivisions named after them. Thus, mottled and brick-red soft sandstones, devoid of fragments of old rocks, and indistinguishable from the beds that make up the Lower and Upper Mottled subdivisions of the Bunter, are found also in the Pebble Beds and in the Keuper Sandstones. Thick beds of massed pebbles are certainly confined to the Pebble Beds; but scattered pebbles, and, more especially, subangular fragments of hard rocks, occur in the higher part of the Lower Mottled subdivision, and still more frequently in the Keuper Sandstones. The same features characterise special lithological types. In parts of the Midlands, fresh pink felspars, in the form of small worn crystals and cleavage-fragments, distinguish the base of the Keuper Sandstones from higher zones and also from Bunter beds; but near Newport such felspar-fragments occur also at various horizons in the latter formation.

Notwithstanding a community of character, in this district Bunter and Keuper are quite probably unconformable. Fortunately the junction is exposed at several places along the bold feature caused by the erosion of the soft Upper Mottled sandrock below the hard Keuper sandstones; in all sections it is either obviously or possibly sharp, and in some is uneven. Also the base of the Keuper is usually conglomeratic, though the fragments may be scattered sparsely along a single line. It has not been possible to determine variations in the thickness of the Upper Mottled formation, but that of the Keuper Sandstone varies from about 20 ft. near Broad Hill, east of Newport, to 400 ft. west of Blymhill; while a boring for water now being put down near Ivetsey Bank has proved 600 feet without reaching the base. The thinning near Newport may be due to overlap of basal members, present at Blymhill and Ivetsey Bank, by higher members, in which case the base, in places at least, is unconformable. Further evidence, however, is needed owing to an uncertainty as to the significance of variations in character and thickness in 'continental' formations such as these, and the known frequency and persistence of horizons of contemporaneous erosion in such formations.

Near Stone, Mr. Robertson finds that the Bunter Pebble Beds with their pebbly sandstones cover the area around Swynnerton, with the exception of a narrow band of Keuper

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Sandstone and Marl, thrown down along the eastern side of the Apedale Fault. Another fault, running east-north-east through the middle of Swynnerton Park and thence by Darlaston and Oulton to Moddershall, throws down Keuper Marl to the south. An inlier of the Keuper Sandstone occurs in the valley of the Scotch Brook, north-east of Stone.

A strip of Pebble Beds runs south-east from Moddershall to Cotwalton. Here, as to the north, in the Stoke-on-Trent Sheet (123), the Pebble Beds seem to be directly overlain by Keuper Marl.

From Swynnerton Park for 8 miles southward to Haughton, dark red and purple Keuper Marl, usually without skerry-bands, is the only 'solid' rock to be seen. Except close to the boundary-fault at Swynnerton Park it is practically horizontal. Good exposures are visible in many places, the higher ground being for the most part free from drift.

Butterton and Swynnerton Dyke.—It has long been known that an igneous dyke cuts the higher parts of the Coal Measures on the southern margin of the North Staffordshire coalfield and extends southwards through the Triassic rocks to the west of Stone.[1] In the southern part of its course this dyke has now been traced in detail by Mr. Robertson from Swynnerton to Heamies Farm near Norton Bridge—a distance of about 3 miles. Its approximate position was detected on Pebble Bed ground just north of Swynnerton village. Thence it bears a little east of south, past the west side of Swynnerton Hall and through Swynnerton Park. Halfway through the park the outcrop is shifted about 150 yds. to the east-north-east, just where the fault already mentioned as throwing down the Keuper Marl is estimated to cross the ground. Whether this shift is due to a displacement of the dyke by the fault or to a diversion of the dyke along the fault is not known.

A short distance north of the fault a poor exposure in a coppice shows the dyke in contact with and enclosing pieces of Pebble Bed (Bunter) sandstone. In Doles Coppice, 150 yds. south of the fault, the dyke (or one branch of it) is 3 to 4 ft. thick, seems to be nearly vertical, and is seen in contact with Keuper Marl.

South of this point the dyke-outcrop traverses no other formation. It appears to run undisturbed to Pilsen's Wood, west of the Highlows, where in one place it has broadened out to an estimated width of over 100 yds. Some of the hand-specimens obtained here exhibit a much more coarsely crystalline texture than any noticed farther north. There are also exposures of much-decomposed material a short distance south of the wood. Nothing more of it is seen *in situ* until we reach the north side of the hill on which Heamies Farm is situated. Here three distinct branches of the dyke are visible, approximately in line

[1] 'The Geology of the Country round Stoke-upon-Trent' (*Mem. Geol. Surv.*), ed. 2, 1905, p. 55.

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with the exposures farther north. Each of these branches is 3 to 4 ft. in thickness, with a very steep dip to the west. The most easterly and most westerly branches are respectively about 24 ft. and 240 ft. from the middle one. South of this point the dykes either thin out or cease to be traceable.

West of the South Staffordshire coalfield, from Wordsley to Himley, Mr. Whitehead finds that the Trias outcrop is divided into irregular blocks by a system of faults that would seem to be the result of adjustments accompanying, or following, the movement along the Western Boundary Fault. A borehole for water at Stourbridge Workhouse,[1] begun in the Upper Mottled Sandstone, reached the Pebble Beds at a depth of about 130 ft. As the base of the Pebble Beds on Cooknell Hill, to the south, is well over 300 ft. above sea-level, it is clear that, immediately to the south of the workhouse, there is a fault that throws the Upper Mottled Sandstone on the north against the Pebble Beds and Lower Mottled Sandstone on the south. This fault appears to run westward to the Pebble Bed escarpment at Lawneswood, where it may join a north-and-south fault, with westward downthrow, known as the Stapenhill Fault. East of this fault, and south of the 'Workhouse Fault,' the ground is occupied mainly by the Pebble Beds, the Lower Mottled Sandstone emerging in small patches against the faults to the east and west. North of the Workhouse Fault, around Kingswinford, Wall Heath, and Himley, the Upper Mottled Sandstone occupies most of the area, the Pebble Beds emerging at the Ridge Hill, at Kingswinford, in Himley Park, and in small patches brought in by faults.

Both the Upper and the Lower Mottled Sandstone seem uniformly brick-red in colour in this district, the 'mottled' character appearing only when the passage into the Pebble Beds is approached.

The Triassic rocks examined by Mr. Eastwood in the Birmingham area consist of the Bunter Pebble Beds, the Upper Mottled Sandstone, the Lower Keuper Sandstone, and the Keuper Marls.

The Bunter Pebble Beds form a continuous belt between Smethwick and California near Harborne, but much of the ground is obscured by drift. From California southward nearly to Northfield they are cut out by a fault that brings in Keuper Sandstone against Keele and Hamstead Beds; but they come in again between the latter place and Rednal. On the north, shingle-beds are abundant; but on the south the bulk of the formation consists of soft red sandstone with occasional small pebbles.

The Upper Mottled Sandstone, which has furnished considerable quantities of moulding sand in Birmingham, may be seen at several places around Hockley and Summer Hill. Until just recently the sand was also obtained from a pit in Dale Street,

[1] Information from Mr. W. Wickham King.

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Smethwick, a locality much farther west than this formation is represented on the old 1-in. map (62 S.W.).

The Keuper Sandstone forms the higher ground of Birmingham and extends beyond the southern margin of the area mapped. Permanent sections are rare; but the formation may be seen in the canal-cutting south of the city, also near Weoley Castle, around Northfield, and in the Cofton railway-cutting. As a rule the sandstone is harder and browner than the Bunter, and can thus be distinguished from the rest of the Triassic sandstones; but in some cases red pellety sandstones similar to those of the Keele Beds render identification of poorly-exposed portions rather doubtful.

The Keuper Marl may be seen in numerous brick-pits to the east and south-east of Birmingham; but the actual junction with the Keuper Sandstone is not visible on account of a fault the existence of which has been proved by borings.

GLACIAL.

In continuation of the work commenced last year (1919) in the Newport (Salop) district, Mr. Dixon has found it possible to distinguish between the deposits of sand and gravel formed when the whole area lying below the 300-ft. contour was flooded beneath the waters of an ice-dammed lake and those earlier ones thrown down or laid bare as the ice-front retreated across the district. Last year some of the latter were attributed to escaping lake-waters. It is more probable that all the eskers and fan-like or delta-form deposits have originated in the ways suggested in the case of certain similar formations elsewhere, viz., that the fans and deltas have been thrown down along the ice-front at the mouths of englacial or subglacial streams during pauses in the retreat, and that the eskers show the courses of the streams. The eskers may have been formed at the mouths of the streams during the periods of more rapid retreat, or they may have accumulated in the stream-channels within the ice and have been merely bared by the retreat. The evidence obtained about Newport is open to either interpretation, but as regards the broad outline of the hypothesis it is unequivocal. The fans and eskers fall naturally into several linear series, each of which may be compared with a string carrying a few beads—the fans. With few exceptions any fan in a series is represented by a similar fan in each of the other series, and these similar fans are found to be so placed that the line connecting them, which according to the hypothesis gives us the position of the ice-front during their deposition, agrees with that position as inferred from the forms and orientations of the fans. Further, in several cases fans are bordered by hollows or by dry channels draining away from them, which seem to demand for their explanation torrents of water pouring off the fans.

The longest, widest, and most continuous of the series that have been recognised up to the present enters the southern

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margin of the area examined at Blymhill, 5 miles south-east of Newport, and follows a north-westerly course past that town, where it skirts the northern end of the high Bunter ground bordering the Coalbrookdale coalfield, to leave the area at Lane End, a run of 10 miles. This series, by its continuity and the obvious resemblance of two of the swellings along it to deltas or fans, gives the clue to the interpretation of the whole. Several small series run almost due west into it, or may be said to branch to the east from it.

The other bands that have been recognised, three in number, lie to the north-east of the major series, and parallel to it, the farthest removed following a line through Littleworth, High Offley, and Knighton (5 miles north-east of Newport). They pass up and down hill in the manner characteristic of eskers.

South of the latitude of Newport these minor series cannot be traced, and the swellings noticeable along the major series, indicative of pauses in the ice-retreat, are small and ill-defined. But at Aqualate Park, Newport, and thence east-north-eastward for 4 miles to Prospect Hill, Knightley, a line of fans in all the series points to a marked pause when the ice-front reached that line. At a mile or so to the north-west another line of fans shows that the retreat was stayed still longer when a line through Chetwynd Park and Littleworth was reached. The fan thrown down during this pause by the main stream is the largest and best example in the district. The alignment of the ice-front during this pause was appreciably more north of east than during the preceding pause. A third pause is marked by a line of smaller fans between Lane End and Knighton, and further swinging-round of the ice-front is proved by the north-north-easterly trend of the line.

Though the lines of fans mark stationary positions of the ice-front, they are quite unlike the 'terminal moraines' that have been recognised in various other regions. In fact it is noteworthy that the deposits at the stationary ice-front have been almost entirely localised to a few places where streams have debouched.

The ice-dammed lake that at a later period covered the area up to the 300-ft. contour has left traces of its shore-line in the form of terraces of sand and gravel, and, much more commonly, in a more or less marked notch or change of slope. Its western and northern limits have not been found; eastward it had a small overflow at Gnosall into the Trent basin. Deposits of laminated clay have been found at many places within its area, but appear to be connected with the fans of the earlier period previously described. They may have been laid down in small temporary sheets of water held up between the ice and the high ground during the retreat across the district.

North of Stone Mr. Robertson finds that the Trent valley is lined with boulder-clay, of unknown thickness, over which

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gravels rise to a height of about 30 ft. above river-level. Valley-gravels are well developed along the Trent and Sow valleys.

The Sow basin, north of Stafford, shows extensive stretches of gravel and sand, but very little boulder-clay. The broad pre-Glacial valleys have been nearly filled with sand and gravel brought down by the streams in late-Glacial or early post-Glacial times, when an enormous quantity of water was flowing. This sand and gravel collected in the side valleys also, *e.g.*, along Gamesley and Doxey Brooks. The modern shrunken rivers now run in approximately the same channels, but beyond the alluvium a slope, often steep, and sometimes 20 ft. or more in height, marks the edge of a sand and gravel terrace. These terraces are well marked along the Sow valley and are sometimes very persistent, *e.g.*, between Great Bridgeford and Stafford. The Sow now meanders over a flat peaty alluvial plain, beyond which on either side a bank of sand and gravel rises and masks with its irregular surface the contours of the original pre-Glacial valley.

An interesting channel, probably of glacial origin, is to be seen in the valley of Scotch Brook north-east of Stone. Just south of Oulton Mill the stream, which runs in a narrow steep-sided valley of Keuper sandstone, turns sharply to the west. About 200 yds. farther on it turns southwards again, round the end of a Keuper sandstone cliff. On the outer side of the first bend the valley widens out a little, and a series of clays, sands, and gravels has been deposited on the side of the sandstone slope to a height of about 30 feet above the present stream-level. There would appear to have been a block at this point, due either to the narrowness of the gorge below or to the fact that the valley beyond had not up till that time been excavated sufficiently deeply.

Overflow probably took place first of all due southward over the top of the sandstone barrier, behind which there is much gravel on the southern slopes. Finally, however, the gorge would be excavated sufficiently to allow the whole discharge to pass through it, leaving the sands and clays banked up at the side of the entrance.

No traces of drift have been found in that part of the South Staffordshire coalfield surveyed by Mr. Whitehead during the past season. To the west of the coalfield the most conspicuous drift feature is the 'esker' near Kingswinford, described by Prof. W. S. Boulton,[1] which extends, within the area surveyed, from Wordsley to Wall Heath. It forms in places a marked ridge. Exposures in it show sand and gravel, false-bedded, and sometimes contorted; with lenticles of clay, and streaks of carbonaceous material in places. In a sand-pit at Wall Heath, these sands and gravels may be seen resting on horizontal Upper Mottled Sandstone, the surface of which slopes westward at about 10°.

[1] *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xiv, pt. 1, 1916, p. 25.

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South of the River Stour, and west of the gap made by that river in the Pebble Bed escarpment at Bell's Mill, south-west of Wordsley, a patch of sand, with lenticles of gravel containing many far-travelled pebbles, lies on the Lower Mottled Sandstone at the level of the adjacent canal. North-west of Himley, clay, or sandy clay, with many pebbles, occupies much of the higher ground, and is exposed to a thickness of about 15 ft. in a cutting of the new Wolverhampton Railway north-west of Himley Plantation.

The fields between Himley and Wall Heath are plentifully strewn with pebbles, of which a certain proportion consist of basalt, and of Coal Measure grits.

Much of the solid rock around Birmingham, in Mr. Eastwood's district, is obscured by drift. West of Warley and towards Halesowen the deposit is thin, and consists of clay and sand with some stones; but eastwards thick deposits completely hide the outcrops of the Trias. From Smethwick through Harborne to California the drift has a thickness of about 80 ft. Though the Glacial deposits are extremely variable, their general succession appears to be : (1) a lower series of tough reddish clays (as seen at California), associated with bedded sands and gravels; (2) an upper series of sands, clays, and loams, mainly unbedded. Far-travelled erratics occur in both series, and include many igneous rocks similar to those of the Arenigs; while of those from a less distant source the Rowley basalt is the most readily identified. Fragments of local sedimentary materials, such as espley rock from the Etruria Marls, and sandstone from the Halesowen and Keele Beds and from the Trias, are also common; while in the Longbridge area Lickey quartzite and Llandovery sandstone are present. The former wide-spread distribution of the drift is probably implied by the presence of erratic boulders over the Romsley area, though that district is now practically free from other forms of drift.

3. Shropshire District.

T. C. Cantrill, B.Sc., District Geologist.
R. W. Pocock, B.Sc. } Geologists.
D. A. Wray, B.Sc. }

During the past season the re-survey of Liverpool and its inner suburbs, begun[1] in 1914 but suspended during the war, has been completed by Mr. Wray. The whole of the Liverpool Sheet (96), with the exception of the area occupied by rocks older than the Coal Measures, has now been revised.

In the Wem Sheet (138) the south-western portion around Baschurch, Middle, and Leaton, has been finished by Mr. Wray, while Mr. Pocock has mapped a wide belt of ground between Wem and Hodnet.

[1] 'Summary of Progress for 1914' (*Mem. Geol. Surv.*), 1915, pp. 11, 12.

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In the Shrewsbury Sheet (152) the north-western margin, traversed by the Severn between Shrawardine and Shrewsbury, has been examined by Mr. Wray.

TRIAS.

In the Liverpool district the 'solid' formations mapped by Mr. Wray are the Pebble Beds and the Upper Mottled Sandstone of the Bunter, and the Basement Beds and Waterstones of the Keuper.

Considerable modification of the original map has been necessary in some parts of the district. Thus the valuable information obtained during the construction of the new outfall sewer[1] from Walton to the Canada Dock fully confirms the original contention ('Summary of Progress for 1914,' p. 11) that the broad belt of Upper Mottled Sandstone shown on the old 1-in. map (79 N.E.) between Walton Hall and Sefton Park is not present. It has also enabled Mr. Wray to locate precisely the position of the main north-and-south faults that traverse the Triassic rocks of Liverpool; and also the base of the Keuper Sandstone, which was found to rest unconformably on the Bunter Sandstone in the tunnel-section under Oriel Road.

The Pebble Beds are well exposed in numerous old quarries at Everton, Aigburth, at West Derby, and also in the extensive cutting on the L. & N.W. Railway at Olive Mount. In the Liverpool District these beds are remarkable for their uniformity.

The Upper Mottled Sandstone consists of soft mottled yellow and red sandstone, and calls for little comment.

The Keuper Basement Beds, wherever exposed, have a gritty sandstone at their base. In the re-survey they have been met with in numerous places at the southern end of the city, and their outcrop has been found to be broken up by numerous parallel north-and-south faults, some of which are visible in the cuttings on the Cheshire Lines Committee's railway to the north of Toxteth and Harrington Docks.

The only exposure of the Waterstones is a narrow faulted outcrop in St. James's Cemetery.

In the south-western part of the Wem Sheet and in the north-western margin of the Shrewsbury Sheet, surveyed by Mr. Wray, it appears that, with the exception of about 2½ square miles on the east of Middle and the north of Pim Hill (an area almost free from drift) the 'solid' geology is largely obscured by a thick mantle of Glacial deposits.

The 'solid' formations mapped are the Bunter Sandstones, the Keuper Basement Beds, the Waterstones, and the Keuper Marl.

The Lower Mottled Sandstone was examined in sections alongside the River Severn at Ford, and also in the village of Ford, where it consists of thinly laminated and fine-grained red sandstones.

[1] The results of the examination of this section are published in *Proc. Liverp. Geol. Soc.*, 1915–1916, pp. 238–251.

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The Bunter Pebble Beds form an outlier at Benthall Cross and Whiston, about half a mile west of Ford. This outlier is shown on the old map (61 N.W.), but has been proved by sections exposed at Benthall Stone to cover a much larger area.

From what is known of the general structure of the district, the Pebble Beds should crop out beneath the broad covering of drift between Nesscliff and Pim Hill on the north, and Ford and Shrewsbury on the south; for the Lower Mottled Sandstone is exposed around Ford, and the Upper Mottled Sandstone on the lower slopes of Nesscliff and Pim Hill; but they were nowhere met with.

The harder beds that characterise the top of the Bunter and have been extensively quarried near Middle (at Webscott, Harmer Hill, and Pim Hill) strongly resemble beds met with in the Ruyton and Nesscliff districts farther west ('Summary of Progress for 1915,' p. 9). In like manner they give rise to a prominent feature in the landscape. They are, however, overlain by white and yellow sandstones, which appear to occupy the same horizon as the Grinshill freestones farther east, and to belong to the Keuper rather than to the Bunter. In the area about Middle the base of the Keuper has, therefore, been taken at the base of these yellow freestones.

It seems highly probable that the harder, dull-red freestones worked in the Ruyton and Nesscliff district represent not only these yellow freestones, but also part of the Upper Mottled Sandstone. As no definite line could be taken as the base of the Keuper at Ruyton and Nesscliff, the dull-red freestones have been mapped as a separate subdivision, and named the Ruyton Sandstones.

Through the whole area the Waterstones are represented by marly and flaggy chocolate-red and yellow sandstones, frequently characterised by small hollows or pores, of the size of a pin's head or of a pea. They are well exposed at Balderton Hall near Middle, and also near the National Schools and Shotton Hall, in the Harmer Hill district.

The Keuper Marl is well exposed in large disused marl-pits to the east of Lea Hall, Harmer Hill, and also at Newton on the Hill and Bilmarsh. At the latter locality it contains a prominent bed of sandstone.

The past year's work has tended to confirm the suggestion made in the 'Summary of Progress for 1915' (p. 9) that the Prees Syncline extends south-westwards to Ruyton and Nesscliff. It is highly probable that the country to the north and east of Baschurch is underlain, not by the Upper Mottled Sandstone, as is indicated on the old map, but by the Keuper Marl. The Keuper escarpment at Middle terminates very abruptly to the north, suggesting a faulted boundary, probably on the line of the powerful north-east and south-west fault well seen to the immediate north of Great Ness. The general effect is to bring the Upper Mottled Sandstone on the south-east against the supposed

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Keuper Marl on the north-west at Prescott, Fenemere, and Middle. The presence of abundant fragments of Keuper skerry sandstone in the drifts of the whole district to the south of Baschurch and Middle tends to confirm this view.

Around Pim Hill and Harmer Hill the structure is complicated by powerful north-and-south faults. One of these faults, which runs immediately east of Pim Hill, carries notable quantities of green copper ore, which was last worked about 50 years ago.

Farther east, the district of Clive, Grinshill, Lee Brockhurst and Hawkstone has been mapped by Mr. Pocock, who finds that all three divisions of the Bunter are present.

The soft, bright red and brown sandstones that form the upper part of the Lower Mottled Sandstone are exposed at Harcourt Park and Rock Hall, near Preston Brockhurst, where they are strongly current-bedded, and are cemented in places by barytes. At one horizon the sandstone is composed of well-rounded millet-seed grains.

The Pebble Beds form the high ground of Besford Wood, Booley, and Stanton, and have been quarried in places, on a small scale, for building-stone. Their base is marked by a bed of calcareous sandstone and conglomerate, which can be seen in the south bank of the Roden east of Lee Bridge, in the lane between Besford and Lee Bridge, and near Harcourt Park. Outliers of the Pebble Beds have been detected at Acton Reynald and Blaze Coppice, near Preston Brockhurst.

The Upper Mottled Sandstone is exposed on the southern slope of Grinshill, and forms most of the high ground at Weston Heath and Bury Walls (north-east of Lee Brockhurst) that was formerly mapped as Keuper Sandstone. No evidence has been found for the east-and-west fault shown on the map as running through Weston.

The upper limit of the Bunter is not well defined, but the line has been drawn to include all the red, fine-grained sandstones within the Upper Mottled division.

The succeeding Keuper Basement Beds consist of fine-grained yellowish to white sandstones, which have been extensively worked for many years at Grinshill as the well-known Grinshill building stone. The quarries show in places a vertical face nearly 100 ft. in height. Quarrying-operations have now ceased on account of the high cost of labour and the great thickness of marl and 'flag-rock' that has to be removed before the building stone is reached.

These white sandstones are well developed near the Red Castle and along the Terrace in Hawkstone Park.

The Waterstones are yellow, brown, and grey flaggy sandstones, evenly bedded, and for the most part of fine grain. They average 20 ft. in thickness at Grinshill, where they are known as the 'flag-rock,' and are used for rough walling and flags; at one time they were employed for roofing also.

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At the base of the 'flag-rock' there is a well-marked bed, averaging 9 in. in thickness, of yellowish sand with black specks of manganese, which is known as 'esk' or 'hess,' a local name for ashes. This bed has been found to persist throughout the area surveyed.

Good sections of the Waterstones and esk-bed are exposed near the obelisk in Hawkstone Park, and also near Marchamley.

The Keuper Marl is of the usual red and grey shaly type, with thin sandstones. The feature separating the outcrop of the Marl from the drift-covered area to the north-west, which was mentioned in the 'Summary of Progress for 1919' (p. 9), has been found to continue north-eastwards towards the Abbey.

The principal fault of the district runs north-eastward through Preston Brockhurst and Lee Brockhurst, throwing down the Keuper Marl on the north-west against the Bunter Sandstones on the south-east, as can be well seen just north of Bridleway Gate Farm near Lee Brockhurst, and at Wixhill near Weston.

Copper ores were formerly worked along approximately north-and-south faults close to Clive Church at Grinshill, also at Yorton Bank, and at Wixhill Hill near Weston.

IGNEOUS INTRUSIONS.

Grinshill and Acton Reynald Dykes.—An igneous dyke, usually only 18 in. in width, has been traced by Mr. Pocock for a distance of two miles from near Holbrook, 2½ miles south of Wem, to the Grinshill Quarries above Acton Reynald. Where it invades the Keuper Sandstone it appears to have ascended along several more or less vertical joints, as four distinct branches have been detected in the hill-side. The dyke is seen again crossing the Upper Mottled Sandstone of the Bunter in a direction 80° east of south in an old lane that leads from the Grinshill road to the quarries. One or other of these branches is probably continuous with one of the dykes at Acton Reynald discovered in 1834 by Murchison,[1] whose observations have been confirmed by information obtained that a dyke passes under the house and tennis-court in a north-westerly direction and forms the side of a well, now built over, in the courtyard. Specimens from this locality have been secured. Murchison mentions another parallel dyke, and also a third, crossing these in an east-north-eastward direction, but no information could be obtained about the two latter.

The rock has been provisionally determined by Dr. H. H. Thomas as an albitised porphyritic basalt, though fresh specimens have since been obtained that may modify this determination.

Dr. Thomas reports that so far as he is aware this dyke is quite unlike any of the others that have been proved to be, or may be, of post-Triassic date.

[1] 'Silurian System,' 1839, p. 295.

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GLACIAL AND RECENT DEPOSITS.

In the Liverpool District mapped by Mr. Wray, numerous borings made in recent years have shown the thickness of the drift to be very variable. Glacial deposits attain their widest development in the south-eastern half of the city.

Along the Mersey shores the boulder-clay forms cliffs 30 ft. high, extending from the Dingle to Otterspool, where it seems to mask a north-and-south hollow in the Triassic rocks.

The Shirdley Hill Sand forms isolated patches preserved in hollows in the boulder-clay. In the neighbourhood of West Derby, where its occurrence has not, it seems, been previously noticed, it attains in places a thickness of over 15 ft. The largest patch occurs around Prince's Park and Otterspool, where it has been dug in comparatively recent times, while it also forms a capping to the adjacent boulder-clay cliffs.

In the south-western part of the Wem Sheet and adjacent margin of the Shrewsbury Sheet, Mr. Wray finds that the Glacial drifts consist of reddish, loamy boulder-clay, with broad spreads of well-bedded gravel and red sand around Stanwardine in the Fields, Baschurch, Broomfields and Montford Bridge. Their thicknesses are extremely variable. Wells and borings have shown them to be 50 ft. thick at Bomere Heath, 100 ft. at Leaton, 96 ft. at Dunn's Heath, and 82 ft. at the Barracks, in the western outskirts of Shrewsbury.

The boulder-clay and the associated gravels consist mainly of slaty Welsh detritus, though granites, apparently of northern origin, and Keuper 'skerry' sandstone, are almost invariably present throughout the district.

Northern erratics appear to be relatively more abundant in the eastern parts of the district. At Leaton, Bicton, Shrewsbury and Preston Montford, the main drift with far-travelled erratics seems to overlie a drift of purely local origin, made up almost entirely of red Triassic sandstone debris.

Shell-fragments are never abundant in the drift, though they have been recorded by Darwin at Shelton Rough, to the immediate west of Shrewsbury, and by Miss Eyton[1] from the now overgrown and disused pits at Merrington Green and Old Wood.

From Ford on the west to Shrewsbury on the east the Severn follows a very meandering course, its total length being nearly 14 miles, while the two localities are only five miles apart. At Ford, in the bed of the river, under a steep bank of boulder-clay, reefs of Lower Mottled Sandstone appear.

The alluvium of the river calls for little comment. It is formed exclusively from the degradation of the drifts and underlying Triassic sandstones. At Ford, Montford Bridge, the Isle, Cross Green, Berwick Park and Gravel Hill, prominent gravel terraces rise 12 to 15 ft. above the level of the recent alluvium.

[1] C. Eyton, 'On the Pleistocene Deposits of North Shropshire,' *Geol. Mag.*, 1870, p. 106.

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These terraces mark an earlier stage in the history of the river. That at Gravel Hill, near Shrewsbury, is intimately connected with an old river-meander, nearly three miles long, which can be traced past Hencott and Ditherington into Shrewsbury. It forms a flat-bottomed and very broad valley, which appears to have been the course of the Severn while the terrace was in process of formation. At a later stage the river cut through the low col between Frankwell and Coton Hill and forsook its former channel, which is now occupied by two insignificant brooks, clearly 'misfits' to the present wide valley. The same process, though not quite so far advanced, is to be seen at the 'Isle,' where a narrow neck, only 350 yds. wide, separates the two ends of a wide meander 4½ miles long.

At the Berth near Baschurch, at Fenemere, and at Eyton, the Glacial sands, which give rise to an undulating and characteristic moundy landscape, are associated with extensive peat-flats.

Farther to the north-east, where surveyed by Mr. Pocock, the high ground extending from Middle to Hawkstone appears to have acted as a barrier to the direct flow of Glacial material from the north-west.

Boulder-clay of a somewhat sandy type occupies most of the low ground south of Grinshill and east of Acton Reynald, the Bunter sandstones appearing only in isolated patches. On the higher ground a few small areas of boulder-clay are found, at Shooter's Hill, near Besford Wood, and around Moston; while the same material covers the ground between Rakepark Lodge and Kenstone, between Weston and Hodnet.

A spread of gravel occurs west of Lee Brockhurst, and sand covers a considerable area round Moreton Corbet. Both these deposits may be connected with an early stage of the River Roden.

4. Cumberland, Westmorland and Furness.

Headquarters: Whitehaven, Cumberland.

B. Smith, M.A., District Geologist.
T. Eastwood, A.R.C.S. } Geologists.
J. Maden, M.Sc. }

Mr. Bernard Smith proceeded to Cumberland early in November to report upon a suitable centre for headquarters, which were finally fixed at Whitehaven. The work of establishing the centre and getting into touch with local interests was then taken in hand. Mr. T. Eastwood, detached from the Midland staff, arrived on December 9th with Mr. J. Maden, whose training in field-work, under the former officer, was commenced on ground that will be some of the first to be mapped systematically in 1921.

Various enquiries as to future prospects in the coalfield north of Maryport and in the iron-ore regions, have been dealt with. Prospecting for hæmatite by boring has been carried on

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extensively during the last few years in the Whitehaven district and as far south as Millom, some of the latest borings being situated at Whitbeck beneath the western shoulder of Black Combe. The search for hæmatite is proceeding in the Vale of Eden also, in an area where abundant fragments of high-grade ore occur in the glacial deposits.

The cores of six borings for iron-ore, three in the Calder Bridge neighbourhood and three near Kirksanton, west of Millom, were examined by Mr. Smith, who discovered grey fossiliferous beds and magnesian limestone in the New Red Series at Kirksanton. More than one boring has been pushed down into fine-grained volcanic rock, riddled with veinlets of calcite, on the assumption that it was Carboniferous Limestone.

Some disturbed and partly-dispersed cores from borings at Hensingham near Whitehaven were examined by Mr. Eastwood.

Detailed records of 14 borings or shaft-sinkings for coal or iron-ore, and abbreviated records of others were obtained. An account of the borings for coal at Bank End and Blue Dial near Maryport, first visited in the early part of the year, and the interesting results obtained, is given in Appendix III., pp. 85–91.

Some of the plans of underground and undersea workings of the Whitehaven Colliery have been transferred to 6-in. Ordnance Sheets.

A series of published 4 miles to 1 in., 1-in. and 6-in. Geological Maps, Vertical and Horizontal Sections, and Survey Memoirs on the district is lodged in the office. These will be available for reference.

Detailed descriptions of the lead and zinc mines of the Lake District, examined by Mr. Eastwood, to form one of the Special Reports on Mineral Resources, are being prepared for publication.

5. Northumberland and Durham.

Headquarters: Newcastle-on-Tyne.

R. G. Carruthers, District Geologist.
C. H. Dinham, B.A.
G. A. Burnett, B.Sc.
F. Marsden, B.Sc.
A. Fowler, M.A., B.Sc., A.I.C.
} Geologists.

The new unit allotted to the North-Eastern coalfield began operations towards the close of the year. It was decided that, in the first place, special attention should be paid to the 'Limestone Coals,' as they are the main reserve in this part of England. There is much doubt over the finer points of correlations and structure amongst these rocks, and a revision of the existing maps is certainly called for. Messrs. Burnett and Marsden have begun work in the Scremerston field, south of Berwick, and have completed the preliminary measurements of

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the typical coast-section, in which they have been assisted by Mr. Fowler.

6. Borings for Oil in Derbyshire and Staffordshire.

The progress at the Petroleum Department's borings for oil in Derbyshire and Staffordshire has been carefully followed; Mr. Bromehead has collected geological information from the seven borings in Derbyshire, Mr. Eastwood from those in Staffordshire; several visits have been paid to the sites and many samples examined in the Survey Office. The following table shows the progress from the beginning of 1920 to the time of going to press, May 1921.

Well.	Depth in January 1920.	Depth in May 1921.	Remarks.
	Ft.	Ft.	
Ridgeway -	2,996	2,996	Abandoned January 1920.
Renishaw -	3,645	4,200	Carboniferous Limestone at 4,100 ft.
Brimington -	2,660	4,040	Carboniferous Limestone at 3,000 ft.
Heath - -	2,955	4,009	Carboniferous Limestone at 3,950 ft.
Hardstoft -	3,112	3,112	No change.
Ironville II -	3,570	4,005	Now abandoned.
Ironville I -	2,580	3,655	Still in Carboniferous Limestone.
Werrington -	1,920	—	Fishing.
Apedale I -	1,350	1,350	Abandoned.
Apedale II -	—	3,450	Started September 1920.

From the economic point of view the results have been disappointing. Hardstoft continues to yield about 1 ton of oil per day by natural flow, but elsewhere only traces of oil have been found. At Heath, the nearest to Hardstoft of the other borings, a few ounces of highly filtered oil were met with at the junction of the Limestone Shales and Carboniferous Limestone at 3,950 ft.; slight indications were also found at Ironville II and Ironville I, notably in the latter at 3,630 ft. This 'show' and that at Heath were torpedoed, but no further yield resulted. The top of the Limestone showed no trace of oil at either Brimington or Renishaw, and there is no reason to modify the remarks on the origin and accumulation of the oil made in the 'Summary of Progress for 1919' (pp. 22, 23).

From the purely geological point of view, it will be seen that all the Derbyshire wells have now reached the Carboniferous Limestone; at Ironville I, 1,600 ft. of that formation has been bored through, without reaching the base. Igneous rocks have been encountered in several of the borings; at Brimington, 850 ft. of lavas, with a few thin intercalations of limestone, have

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already been proved. As was expected, both the Lower Coal Measures and Millstone Grits show a steady increase in thickness from south to north.

In Staffordshire, Apedale No. II well was started a few yards distant from No. I well, which was abandoned, the horizon being just above the Bullhurst Coal. At November 9, 1920, the depth was 1,060 ft. in Coal Measures, and the rocks penetrated were sandstones, shales and several coals. At about 1,465 ft. red and green ashy material was entered, approximately at the top of the Millstone Grit, and this continued to a depth of 3,450 ft. (March 23, 1921). This great thickness of volcanic strata was not expected in the bore, as no similar rocks are known to occur near this horizon except at Astbury (Staffordshire) and Ashover in Derbyshire, where they are comparatively thin.

(B)—SCOTLAND.

The field-work in the Highlands has been proceeding in two districts :—

1. West Highland District under Mr. E. B. Bailey, M.C., B.A.
2. North Highland District under Mr. M. Macgregor, M.A., B.Sc.

The coalfield revision was carried on in two districts :—

3. In North Ayrshire under Mr. E. B. Bailey, M.C., B.A.
4. Stirlingshire and Clackmannanshire District, and part of Lanarkshire (Douglas Coalfield), under Mr. M. Macgregor, M.A., B.Sc.

1. West Highland District.

E. B. Bailey, M.C., B.A., District Geologist.
E. M. Anderson, M.A., B.Sc.
J. E. Richey, M.C., B.A.I.
G. V. Wilson, B.Sc.
G. A. Burnett, B.Sc.
} Geologists.

The area surveyed lies mainly in Mull and adjacent islands including Staffa and Iona, Sheets 43 and 51 of the 1-in. Map of Scotland. A commencement has also been made in Ardnamurchan, Sheet 52.

PRE-MESOZOIC ROCKS.

Iona.—The presence in Iona of Lewisian Gneiss, with associated marble, and of sediments strongly recalling the Lower Torridonian of Skye has long been known, and their distribution has been roughly indicated by Sir Archibald Geikie in his 'Geological Map of Scotland' 1892. Mr. E. M. Anderson adds a new locality for the sediments of Torridonian type, for besides forming a strip along the eastern side of the island, they

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compose Eilean Chalbha and the neighbouring foreshore of the north-western coast.

Undoubted altered sediments within the Archæan complex occur (1) in the neighbourhood of the marble quarry, near the most southerly point of Iona, and (2) to the north of Dun Cul Bhuirg, on the western coast. The quarried marble is an almost vertical band about 20 ft. in thickness, pure white in colour, or white with characteristic greenish streaking. It is associated with other certainly sedimentary material, including a dark graphitic rock, which must be an altered shale.

The sediments to the north of Dun Cul Bhuirg also include bands of marble, one of which has been worked to a very small extent for ornamental purposes, under the name of the 'Silverstone.' It is a pinkish marble, variegated by grains of green serpentinous material, and 'silvery' from the presence of pale-coloured mica, no doubt magnesian. There is also at this locality a broad band of brown biotite-gneiss, very massive and unbanded in its weathered appearance. This passes into a graphite-schist, which is in part pyritous, and is strongly reminiscent of a type found elsewhere in Scottish Archæan sediments.

A period of intrusive activity followed the deposition of these sediments, as is shown by the presence among them of very fine hornblende-schists or epidiorites. They are also cut by coarse unfoliated bands of pegmatite of a type already noted by Mr. Craig in the adjacent island of Soa.[1] As pegmatites are almost entirely absent from the neighbouring sediments of Torridonian facies, their occurrences in the cases just referred to would seem to belong to a late phase of igneous activity of Archæan age, a phase which it is to be noted was later than any period of metamorphism and shearing movements.

Unfoliated pegmatites are everywhere the latest intrusions of the Lewisian complex of Iona, and are by no means confined to areas of undoubted sediments. The basis of the igneous gneiss consists in large part (1) of banded granitic rocks, sometimes containing a certain amount of hornblende in their darker laminæ, and (2) of massive hornblende-gneisses, much coarser in grain than the hornblende-schists already mentioned. The whole formation throughout the island is much veined and irregularly intergrown with epidote. A local concentration of magnetite will be noted on p. 43.

The supposed Torridonian series of the eastern strip in Iona may be roughly divided as follows :—

(2) A younger flaggy group characterised by rapid alternations of more siliceous and more shaly material.

(1) An older group of grits and conglomerates with subordinate shale.

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[1] E. H. Cunningham Craig, 'The Geology of Colonsay and Oronsay, with part of the Ross of Mull' (*Mem. Geol. Surv.*), 1911, p. 79.

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A coarse conglomerate can be seen at certain points along the old gneiss margin. The commonest constituents are fragments of granitic rocks evidently derived from the gneiss, and of any size up to two or three feet in length. Boulders of hornblendic rock and of quartz are also occasionally present, as, for instance, at the dividing line of the two formations at the most northerly point on the island. The conglomerate is interbedded with and overlain by pebbly grits, in which the small pebbles consist of quartz and felspar, while the matrix, like that of the conglomerate, is dark grey or dark green in colour. Less commonly, the base is more yellowish green, suggesting epidote. The part of this formation next to the gneiss shows signs of rather intense crushing, perhaps because it acted as a zone of weakness during some period of stress. There is, however, so far as has been observed, no definite break or thrust along the margin. It is important to realise that the crushing referred to above does not introduce uncertainty in the interpretation of the conglomerates. A visit to the wave-washed exposures at the Pigeon's Cave on the south coast is enough to settle this point. There conglomerate layers are interbedded with grits and shaly layers, and one notes that the included fragments differ markedly in character from their surrounding matrix. The crushing manifests itself in the disruption of the bedded series, it does not produce anything approaching a crush-conglomerate.

The later portion of the grits is interbedded with bands of shale, some greenish, others dark and probably carbonaceous, while there is a broad band of dark shale intervening between the last of the grits and the succeeding flags.

The sediments of the north-western coast and Eilean Chalbha are somewhat puzzling in character, but may very possibly represent some part of the conglomeratic group (1) of the east.

The puckering and cleavage which have affected the similar rocks of Colonsay and Islay are almost absent in Iona. Apart from the movement near the margin of the gneiss, these sediments show little sign of dynamic metamorphism. Their bedding is, however, everywhere steeply inclined, E.S.E. in the eastern outcrop, and south-east in the north-western.

The Ross of Mull Granite must underlie a considerable part of the Sound of Iona, as since Macculloch's day it has been known that three small islets close to the Iona shore are composed of granite of the Ross type. It is interesting to note that the band of shale between the grits and the flagstone group has a spotted appearance where it comes near these islets, but not elsewhere. This alteration would seem to prove the post-Torridonian age of the granite, which has hitherto been somewhat in doubt. To avoid confusion, it should be added that Macculloch speaks of an 'appearance of transition' into the granite, but was probably misled by the presence of felspar grains in the flagstone series and also among the grits.

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The unfoliated post-Torridonian intrusions of Iona belong to two classes :—

(1) Basic dykes (apparently basalt and camptonite) run in every azimuth between N. 30° W. and due east and west. Some at least of this group are probably Tertiary, and so do not come under the heading of this section.

(2) The second class includes lamprophyres, which are somewhat irregular but show a marked tendency to follow a series of north and south joint-planes, which dip westwards throughout the island at angles of about 30°. It also includes a group of more acid intrusions, usually pink in colour, and sometimes with basic margins. These occasionally follow the joint-planes referred to, but more often are irregularly rolling with a tendency to horizontality. It is possible that the whole of this class of intrusions are of the same period as a set of mica-traps, granite-porphyries, and porphyrites, found by Messrs. Craig and Bosworth,[1] to cut the Ross of Mull Granite while themselves cut by certain north-westerly dykes. Further evidence of the age of the Ross intrusions will be given presently in the description of Gribun.

Gribun.—Iona has been interpreted by Mr. C. T. Clough[2] as probably a part of the foreland of the Moine Thrust. The thrust itself may be hidden in the Sound of Iona or obliterated by the Ross of Mull Granite; at any rate the well-known gneiss of Erisgeir, Inch Kenneth, and Gribun, with the fuller succession of the Ross, almost certainly belong to the Moine series.

Mr. E. B. Bailey and Mr. G. A. Burnett have found the gneiss just mentioned to be remarkable for its pebbly character. It is a false-bedded arkose-gneiss, retaining much of its sedimentary aspect despite a somewhat high crystallization with a development of garnets in certain micaceous partings.

Two steep sheets of coarse mica-trap have been found by Mr. Bailey on the shore N.W. of Balmeanach traversing the Gribun gneiss and themselves cut off by the unconformable Trias. They dip N.W. and almost certainly belong to the same series as the numerous mica-trap sheets recorded by Mr. Bosworth in 1909 as cutting the Ross of Mull Granite. Thus additional indirect evidence is afforded for Judd's generally accepted view that the Ross Granite is of pre-Mesozoic age.

MESOZOIC ROCKS.

Gribun and Inch Kenneth.—Prof. Judd's classic description supplies the natural datum from which to reckon further advance.

[1] E. H. Cunningham Craig, 'The Geology of Colonsay and Oronsay, with part of the Ross of Mull' (*Mem. Geol. Surv.*), 1911, p. 86.
T. O. Bosworth, 'Summary of Progress for 1909.' (*Mem. Geol. Surv.*), 1910, p. 27.

[2] C. T. Clough in 'The Geology of Colonsay and Oronsay, with part of the Ross of Mull.' (*Mem. Geol. Surv.*), 1911, p. 77.

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Prof. Judd[1] recognised Poikilitic, Upper Greensand (Cenomanian), and silicified Chalk. Some years later Mr. J. S. Gardner[2] discovered Lower Lias in the much landslipped Wilderness (north and south of Aird na h-Iolaire), and corrected Judd's mistaken impression that Greensand is to be found in Inch Kenneth. In addition, Gardner questioned whether Judd's 'Chalk' was *in situ*, for he thought it all *remanié* in Tertiary deposits, but in this he went too far, as may be seen for instance in Allt na Teangaidh, just below the main road.

The results of last year's work may now be briefly stated. The various groups were mapped by Mr. Bailey, the main exposures were measured by Mr. W. Manson, who collected 750 fossils, and the examination of these has been started by Dr. G. W. Lee.

Judd's Poikilitic—or Trias, as one is justified in calling it—is some 200 ft. thick at Inch Kenneth, where the gneiss floor disappears below the sea, and about 10 ft. thick 2½ miles farther south where gneiss rises 700 ft. in the coastal cliffs of Mull. An unrecorded feature is the abundance of pebbles of red Torridon arkose and fine grained (? Durness) limestone. Some of these far-travelled limestone pebbles are enclosed in an envelope of chert.

For about 2½ miles along its outcrop the Trias is succeeded by definite Rhaetic. The prevalent type is dark sandy limestone, or calcareous sandstone, with rather wavy bedding and no trace of concretionary structure. Lamellibranchs are numerous. The best section is in Allt na Teangaidh near Balmeanach, where about 30 ft. are laid bare. The fossils include *Pteria contorta* [*Avicula*], *Gervillia præcursor*, and *Pecten valoniensis*. This is the second record from Scotland of demonstrable Rhaetic beds—the only occurrence known hitherto is the mass of shale found by Messrs. Peach and Gunn tumbled down the throat of a Tertiary volcano in Arran.

In the Wilderness the Trias is succeeded in a low cliff south of Uamh nan Calman by shales and cement-stones. Although the section suggests continuous deposit there is nothing of the type of the Balmeanach Rhaetic—no fossils could be found, but the facies of the shales and argillaceous limestones is distinctly Liassic. What follows is confused by landslipping, but in small cliffs south of Aird na h-Iolaire the lower part of the Hettangian is very definitely represented, and in associated loose blocks one finds a Sinemurian fauna. Taken together these correspond with the Broadford Beds of Skye.

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[1] J. W. Judd, 'The Secondary Rocks of Scotland.' *Quart. Journ. Geol. Soc.*, vol. xxxiv, 1878, pp. 694, 732. See also a critical discussion of the unconformity at the base of the Gribun Secondaries, J. Macculloch, 'Western Islands of Scotland,' vol. i, 1819, p. 563.

[2] J. S. Gardner, 'Leaf Beds and Gravels of Ardtun, Carsaig, etc. in Mull.' *Quart. Journ. Geol. Soc.*, vol. xliii, 1887, p. 284.

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The Hettangian of the cliff section is divisible into two :—

(*a*) One ft. red mudstone, overlain by 19 ft. mostly micaceous calcareous sandstone, 8 ft. sandy limestone and calcareous shale crowded with *Ostrea liassica*, overlain by

(*b*) Twenty ft. shales and limestone assignable to the Planorbis Zone.

The Oyster Bed facies, characterising the upper part of (*a*), is well known in the lower Hettangian of England and again in Skye, but not elsewhere in Mull. The *planorbis* fauna of the lower Hettangian has never hitherto been forthcoming in Scotland, though carefully searched for.

The Sinemurian fauna has been found, as already stated, in loose blocks. One may mention *Lima gigantea* indicating the lower part of the Sinemurian, and typical *Gryphaea arcuata*, also betokening Sinemurian but not necessarily its lower stages.

Prof. Judd, the original discoverer of Cretaceous rocks in Scotland, emphasized the bearing of his observations upon Suess's generalisation regarding the Upper Cretaceous transgression of the European area (*op. cit.*, p. 683). For instance, in the Gribun peninsula nothing remains between the Lower Lias and the Cenomanian.

Dr. G. W. Lee, some years ago, justified Judd's employment of the name Cenomanian for the Greensand of Mull by finding a zonal ammonite near Loch Don. The best Gribun exposure is below the road in a great landslip N.E. of Balmeanach. Oyster banks with *Exogyra conica* and occasional *Serpula* are very conspicuous. Additional fossils to those recorded by Judd are : *Pecten orbicularis* and *Pecten asper* (?). Judd's *Spongia paradoxica* is probably based on highly characteristic sandcasts, and Mr. Bailey points out that these resemble forms common in the Upper Greensand of Eastbourne for which Mr. Clement Reid[1] has offered a very different interpretation.

The Greensand of Gribun may be taken as about 20 ft. thick. Above follow white sandstone 10 ft. and Chalk 10 ft. The white sandstone has not previously been described from Gribun, but it is in keeping with Judd's general sequence.

Ardnamurchan.—Mr. J. E. Richey commenced the examination of the Ardnamurchan Secondaries. In the cliff west of Sron Bheag, the southernmost point west of Kilchoan, there is a mass of baked sedimentary rock which is probably Inferior Oolite. It is about fifty feet thick and has a distinct resemblance to Chalk; the exposure is rather inaccessible and has not yet been fully examined.

TERTIARY SEDIMENTS IN MULL.

Mr. Bailey has found that the silicified chalk of Gribun is veined by sandstone, and that in places (*e.g.*, Allt na Teangaidh) similar sandstone constitutes a thin overlying bed. This sandstone shows marked wind-rounding of its grains, and may, there-

[1] Clement Reid, 'The Geology of Eastbourne.' (*Mem. Geol. Surv.*), 1898, p. 5.

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fore, be claimed as a desert deposit. Another interesting point is that the silicification of the chalk is of later date than the desert sand. An extension of the chert which replaces the chalk in many cases serves as matrix to the grains of sand. Elsewhere it is commonly found that the grains have added fresh crystal facets, and thus lost much of their rounded outline.

To investigate the extent of this Tertiary desert sand, a visit was made to the Tertiary sandstone of Carsaig. Wind-rounding was here again very evident, and included fragments of silicified chalk were seen surrounded by a halo of chert serving as a local matrix for the adjacent sand-grains.

In Allt na Teangaidh the desert sand is overlain by the thin, red mudstone so often met with at the base of the Mull lavas. This deposit, and the somewhat later leaf-beds and coal-seams, obviously indicate a change of climate.

TERTIARY LAVAS.

Local discordance, Bloody Bay, Tobermory.—A general feature of the Mull lavas is the even way in which they follow a thin layer of Tertiary sediments which in turn rests with misleading conformity on underlying Mesozoic rocks. Mr. G. V. Wilson has found a most unusual appearance presented in an old sandstone quarry in the sea cliff of Bloody Bay. The locality is about 1¼ miles S.E. of Ardmore Farm and of easy access from above, or by boat from Tobermory. Prof. Judd, speaking of the sandstone, justly remarks: "the eroded surfaces of these beds is seen to be directly covered by the . . . basaltic lavas" (*op. cit.*, p. 715). The most interesting feature of the exposure is the peculiar way in which the flat-bedded sandstone juts up as a knob into the overlying lavas (Fig. 1). Along

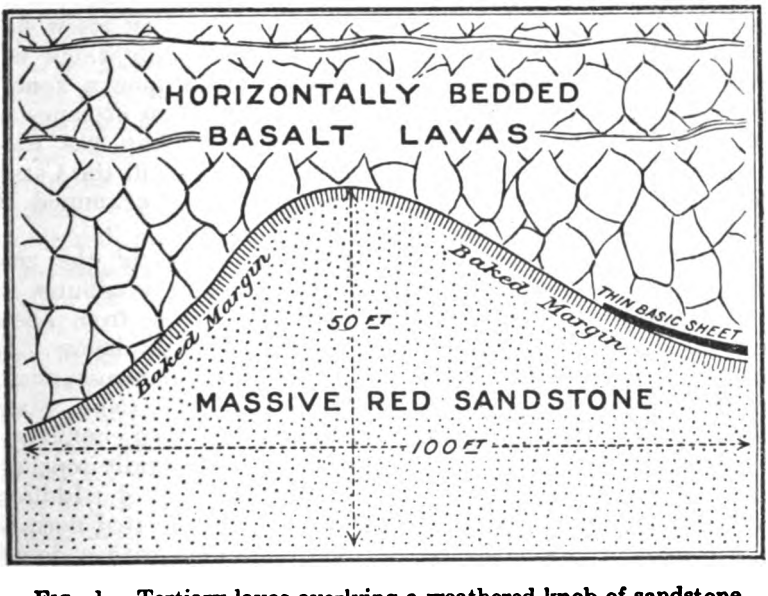

FIG. 1.—Tertiary lavas overlying a weathered knob of sandstone at Bloody Bay.

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the line of contact the sandstone shows a baked zone which extends inwards for several inches.

The sandstone is of good quality and has been used in the wall of the path leading to Rudha nan Gall Lighthouse. It is at least 50 ft. thick, current-bedded and red in colour, with a small proportion of rounded grains. It also carries irregular concretionary bands of iron-ore. The outcrop can be traced for about 200 yds. and is terminated in both directions by what appears to be a fault running almost parallel with the cliffs and bringing basalt lavas down to sea-level. The age of the sandstone remains doubtful.

Columnar Lavas, Staffa and elsewhere.—The cliffs of Gribun have enabled Mr. Bailey to realise that the columnar lavas there seen all occupy a very low position in the Plateau Lava group of Mull. Comparison with other districts is rendered somewhat unsatisfactory, as columnar structure is often poorly displayed in ordinary inland exposures, but it seems certain that all the columnar lavas of Mull are of relatively early date. They have a geographical as well as a time limit. They reach their fullest development where mapped by Mr. Anderson in the cliffs west of Carsaig, whence they continue by Ardtun into the Gribun peninsula, Ulva and Staffa. Reidh Eilean, outside Iona, has yielded Mr. Anderson a hitherto unrecorded occurrence of columnar structure of spectacular type, but the columnar rock in this case is of unusually doleritic texture, and its field relations are hidden by the sea. The only columnar lava not falling within the south-west corner of the Mull district is an example noted by Mr. Wilson towards the base of the series at Bloody Bay, near Tobermory.

A feature of a large proportion of the columnar lavas of the Mull area is their triple-zoned appearance. They often have a thick slaggy top merging down into an equally thick zone of narrow wavy columns, which rests in turn upon a zone of more massive vertical columns. This combination of zones has received little attention in previous writings, but was noted some years ago by Mr. Anderson and Mr. Wilson in the Carsaig cliffs. It is nowhere better seen than in Staffa, examined last year by Mr. G. A. Burnett.

Prof. Iddings gives a very useful discussion of the zonal jointing of analogous American examples, and attributes the upper zone of columns to irregular rapid cooling from above, and the lower zone to regular slow-cooling from below. His interpretation accounts for a very striking phenomenon visible on the foreshore a little north of the Clamshell Cave, Staffa. Here the two systems of joints, instead of becoming confluent at their contact, as is often the case, seem to be mutually repellant, for they suddenly swing into parallelism. Prof. Iddings'[1] explanation is that the jointing tends to be propagated normally to a retreating isothermal surface corresponding with a definite

[1] J. P. Iddings, 'Igneous Rocks,' vol. i, 1909, figs. 13, 15, 16, p. 322.

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temperature, and that when cooling from above and below brings two such surfaces together the form of the combined surfaces is materially modified by a rounding off of the angle of contact—from which follows a corresponding deflection of the developing joint-planes. On the other hand, the commonly observed confluence of the two sets of joints is, of course, to be interpreted as evidence of the influence which two approaching joint systems may exercise upon one another, and is not to be taken as a contradiction of Prof. Iddings' explanation.

The two columnar zones of the Fingal's Cave lava of Staffa are among the most familiar of geological phenomena, though they have been previously ascribed to independent flows in Sir A. Geikie's descriptions. Mr. Burnett has shown their true relationship. He has also found that the northern half of the traverse between Clamshell Cave and Goat Cave affords an excellent coast section of the top zone of the Fingal's Cave lava consisting of commingled slag and solid, merging finally to pure slag. In the mixed part of this uppermost zone early masses of slag have clearly been involved in, and carried forward by, still liquid portions of the flow, the latter now represented by columnar basalt. At Goat Cave the slaggy top of the Fingal's Cave lava is covered by a few feet of carbonaceous and ashy sediment, which in turn is overlain by further basaltic flows constituting Meall an Fulann.

It has long been known that the Fingal's Cave lava is underlain by red ash. A convenient exposure can be reached from above at Port an Fhasgaidh. The massive columns here reach down to about a foot from the ash, but the bottom layer of the lava is brecciated and vesicular. A 1-ft. sill of basalt, chilled at top and bottom and clearly transgressive, lies just a little below the lava base.

The Fossil Tree of Burgh.—Another famous columnar lava of the district is that which flowed round and over the fossil tree of Burgh—to use a now familiar name. The cast of this tree trunk stands in a recess of the coastal cliff of the Gribun peninsula, 150 yds. north of the waterfall of Allt Airidh nan Caisteal. Geologically speaking it is the most wonderful spectacle in all Mull, and like so much else of interest in the west of Scotland, was made known over 100 years ago by Macculloch. Sir Archibald Geikie has published a photograph in his Text Book of Geology (1903, p. 758). The cast of the tree is seen in vertical section, and looks like a pipe, nearly 5 ft. broad and about 40 ft. high, and largely filled with breccia consisting of lumps of 'white trap' and charred wood. The lower part of the pipe encloses a partially silicified semi-cylinder of wood glittering with quartz crystals. The diameter of the cylinder is about 3 ft., and outside is a hollow where soft black coniferous wood, a couple of inches thick, may be dug out with a hammer. In Macculloch's day the wood continued as a coat around the silicified cylinder, but since then has been ruthlessly stripped away by curio-hunters.

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The pipe rises in the heart of a columnar basalt, and the columns as they approach it turn so as to meet it everywhere at right angles. Geikie and Gardner have described the pipe as reaching right up through one lava and overlain by another, but such is not the case. Macculloch seems to have thought that the tree had somehow found its way into a fissure of the basalt.

A prostrate tree is included in a brecciated portion of the same lava exposed in a cave 230 yds. north of the upstanding tree. It is probable, Mr. Bailey says, that these two trees are mere remnants of a forest. At any rate the lower part of the lava in this neighbourhood has very unusual characteristics. It rests regularly on a thin carbonaceous layer following an important ash, but within itself it is wonderfully irregular. It consists, in fact, of a chaotic assemblage of columnar and more or less brecciated vesicular basalt. The columnar basalt traverses the brecciated, or sweeps round great masses of it 40 or 50 ft. high. Everywhere the columns are at right angles to the line of contact, no doubt because the slaggy breccia could offer practically no resistance to contractional force during cooling. The columnar basalt sometimes comes in contact with the underlying carbonaceous mud, and is distinctly chilled, as has been found to be the case with a few other lava bases in Mull; but it is unchilled where it joins the breccia.

The lava is unusually thick, and the irregularity of its basal part may be looked upon as a special feature. Apart from this it exhibits the triple zoning already mentioned as characteristic of the Fingal's Cave lava, etc.

Flow-Banding and Pipe Amygdales.—A curious type of flow-banded lava has been met with in many parts of the district surveyed last year, more particularly in Gometra mapped by Mr. Burnett; the banding is often sufficiently lenticular to remind one of pillow structure, but the lenticles are, on the whole, much too elongated to be called pillows, and they are not defined by noticeably chilled margins. Each band has typically three layers, a basal zone with pipe-amygdales, a middle solid zone, an upper zone with crowded little rounded amygdales. There is a distinct separation of the bands, for nowhere can one point to round vesicles of the top of one band extending up among the pipes of the next. Mr. Richey has found a section at the roadside 350 yds. E. of Kilninian Church, which throws considerable light upon the conditions attending the formation of this banding. Reddening such as is commonly attributed to surface weathering during the volcanic period, extends along the junction lines of the successive bands; this seems to point conclusively to an imperfect contact of the bands, so that it is fair to regard the banding as a surface phenomenon resulting from successive overflows upon the surface of a parent lava.

Pegmatitic Veins.—Several examples of contemporaneous pegmatitic linings to vesicles, and of associated veins, have been encountered this year in basaltic lava flows. Mr. Bailey had

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previously noted the phenomenon on the shores of the sound of Mull, and Dr. McLintock[1] has described it from the Ben More district. The interest of the recent finds is their occurrence outside the area of pneumatolysis of central and eastern Mull. The pegmatitic veins, where, for instance, they have been found by Mr. Burnett in Gometra, are seen stringing basalt lavas which still carry their olivine in large measure unaltered.

Ben More Mugearite.—Sir A. Geikie,[2] in separating a pale group of Mull lavas forming the upper portion of Ben More, spoke of the occurrence among them of trachytic flows. During the survey of the district it was thought that Geikie's trachytic flows were really a great mugearite sill, and this statement has been published. On the other hand, Mr. Wilson, in the Loch Buie district, definitely recognised as lavas certain mugearites which evidently occupied much the same stratigraphical position as the mugearite of Ben More. Accordingly, Mr. Bailey investigated the matter last season, and states that the continuation of the Ben More mugearite south of Kinlochscridain can be shown to be a lava with a weathered, slaggy top. In keeping with this, Mr. Richey has found a thin sedimentary layer, immediately above the mugearite in Ben More itself, containing numerous fragments of mugearitic type. Moreover, the section which led to the view that the mugearite was intrusive, when examined this year by Mr. Bailey and Mr. Anderson, proved to be misleading.

TERTIARY INTRUSIONS.

Mull Sills.—Messrs. Bailey and Anderson have completed the mapping of the Loch Scridain area of sill-intrusion, and Mr. Wilson has found and mapped a distinct area in the northern end of the island. In both cases the sills are very transgressive.

Among the noteworthy features of the Loch Scridain sills are :—

(1) frequent residuum of pitchstone,
(2) numberless highly altered xenoliths,
(3) occasional and local absence of chilled margins.

(1) and (2) of the above have often been described already. Mr. Bailey has now found instances combining all three characteristics, as, for instance, at Scobull Point, Loch Scridain. Messrs. Anderson and Radley[3] have pointed to the pitchstone residuum as evidence of retarded crystallization, and have argued that it has been determined by an unusually high water-content in the magma supplying the sills. Mr. Bailey points

[1] W. F. P. McLintock, 'On the Zeolites and Associated Minerals from the Tertiary lavas around Ben More, Mull.' *Trans. Roy. Soc. Edin.*, vol. li, 1917, pp. 15, 18, 21.

[2] A. Geikie, 'Ancient Volcanoes of Great Britain,' vol. ii, 1897, p. 214.

[3] E. M. Anderson and E. G. Radley, 'The Pitchstones of Mull and their Genesis.' *Quart. Journ. Geol. Soc.*, vol. lxxi, 1915, p. 205.

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out that the characteristics (2) and (3) suggest retarded consolidation in contact with cold surfaces, not by any means the same phenomenon as retarded crystallization, but very likely attributable to the same cause.

Mull Dykes.—The belt of N.W. dykes belonging to Mull is about 10 miles broad. Mr. Wilson has found that the topography of northern Mull, within the belt, is lineated N.W. and S.E., in striking contrast to that of adjacent districts.

Ardnamurchan Complex.—In a preliminary investigation of the Ardnamurchan peninsula, Mr. Richey has confirmed Dr. Harker's[1] announcement of a well-defined belt of centrally inclined basic sheets (cone-sheets). The sheets dip to a common centre, which is situated approximately beneath Beinn na h-Imeilte, between Sanna Bay and Kilchoan. The belt can be traced round half the circumference of a circle, extending from Faskadale on the north side of the peninsula to the south-west side of An Acairseid. It is at any rate three miles in annular width. The sheets composing the outer half of the belt are individually the more massive, and attain unique development on Ben Hiant,[2] where single members are upwards of 100 ft. thick. The dip also varies, becoming gentler towards the exterior of the belt, as, for example, in the Ben Hiant district.

The great gabbro mass, long known to form the western part of the peninsula, has a steep or vertical junction, which follows closely the strike of the belt of cone-sheets. It is considered to be later than the sheets for the following reasons :—

(1) The gabbro is free from the sheets, whereas the sheets occur in great force immediately outside it.

(2) The sheets, together with their country rock, become increasingly altered by thermal metamorphism towards the gabbro junction.

(3) An isolated area of basalt lava traversed by sheets, presumably belonging to the set of cone-sheets, was observed surrounded by gabbro on Meall an Tarmachain.

PREGLACIAL MARINE EROSION.

The district includes many evidences of Preglacial marine erosion at about 100 ft. above sea level, already described by Mr. Wright,[3] whose conclusions have been confirmed. Of cognate interest is an old sea cave at a higher level, to which Mr. Burnett's attention was directed by Mrs. Clark of Ulva. It opens on the south-east slope of A'Chrannag, Ulva, and its floor, where reached in a trench, lay 150 ft. above high-water mark. It measures

[1] A. Harker, 'Anniversary Address of the President.' *Quart. Journ. Geol. Soc.*, vol. lxxiii, 1917, part 1, p. xciv.

[2] A. Geikie, 'Ancient Volcanoes of Great Britain,' vol. ii, 1897, pp. 318–322.

[3] W. B. Wright, 'Preglacial Shoreline in the Western Isles of Scotland.' *Geol. Mag.*, 1911, p. 97.

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40 ft. broad, 50 ft. deep, 25 ft. high, and its bottom is covered with a deposit of boulder-clay up to 5 ft. thick, charged with granite, gneiss, and Liassic limestone derived from Morvern and the Sound of Mull. The far-travelled erratics are, taken together, much more numerous than basalts such as might have come from the island itself. The level corresponds with that of a well-marked, though heavily glaciated, shoreline found some years ago by Mr. Anderson at the head of Loch Scridain.

ECONOMICS.

Iron Ore, Iona.—Magnetic iron ore was known to have been found near the southern end of Iona. Mr. E. M. Anderson reports its occurrence at two localities :—

(*a*) Close to the shore directly north of the eastern end of Eilean Musimul. The material here forms a vertical band from 2 ft. to 4 ft. in width, traceable for about 200 ft., and running parallel to the banding of the adjoining gneiss. The magnetite is mixed with garnet and other impurities, but the state of concentration is, perhaps, rather greater than that of the next locality.

(*b*) Close to the shore just west of Port an Fhir-bhreige (the western part of St. Columba's Bay). There is here a zone of impregnation some 10 or 15 yards in width, which can be traced for nearly 100 yards; but the deposit is most irregular, and only a small part of this thickness can be classed as even inferior ore.

Until assays of the material have been made, it is not possible to estimate the amount of iron, and it is likely that the limited nature of the deposits so far apparent would prevent them from being profitably workable.

Marble, Iona.—The well-known Iona marble quarry has not resumed working since the war. The stone was used for interior decoration, especially in churches. The available reserves are not sufficient to allow the development of the industry on a large scale, but would probably meet a limited demand for many years to come.

Sandstone, Bloody Bay, Mull.—Attention may be directed to the sandstone of Bloody Bay, described on p. 38. It has already been quarried for the Rudha nan Gall lighthouse, and is a serviceable stone on the water's brink should building material be again required in this locality.

Lime, Mull.—The white sands of Calgary Bay could supply an inexhaustible supply of lime. Mr. Wilson reports rather more than 70 per cent. of $CaCO_3$ in a type sample.

The cornstones at the entrance of Loch na Keal might perhaps be used for local purposes. The most favourable outcrop is that of the sea-cliff below Inch Kenneth Chapel.

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2. North Highland District.

M. Macgregor, M.A., B.Sc., District Geologist.
C. H. Dinham, B.A.
H. H. Read, B.Sc., A.R.C.S. } Geologists.
D. Haldane

Field-work was resumed during the past season in the North Highland District, and considerable progress made with the survey of One-inch Sheet 102. The ground surveyed lies in the south-eastern quarter of the sheet, partly in Sutherland, partly in Easter Ross.

EASTER ROSS.

In the Ross-shire ground, Mr. Dinham surveyed an area lying north of the lower part of Strath Carron. The greater part of this tract is covered by morainic drift, and the rocks, which are found only in the stream sections and along the shores of the Kyle of Sutherland, consist of the usual siliceous granulites of Moine type, with thin and rare pelitic bands, scarce sills of chloritic and garnetiferous hornblende-schist, and lamprophyres of two types, distinguished by brown and brick-red weathering. Near Culrain, where the Kyle first narrows, the top of Lamentation Hill (Creag a' Choineachan) and the ground to the west of it are comparatively free from drift. At the very summit of this hill outcrops a brown-weathering lamprophyre, with abundant well-rounded inclusions of schist and of a pink granite. The contrast between the resistance of this tough, scarcely jointed rock to the action of ice, indicated by its tendency to occur in rock knobs, and its easy susceptibility to ordinary atmospheric weathering, is well illustrated here. This dyke has been traced at intervals for at least 1,000 yds. to the W.N.W.; in the opposite direction it is probably continuous, though the connection is not visible, with the exactly similar dyke of Sithean Mor across the Kyle (p. 47).

The 50-ft. Raised Beach forms a well-marked flat here and there on the west shore of the Kyle. At the lower end of Strath Carron the sands and gravels of this beach must have constituted a delta, the greater part of which was situated below the level of tidal waters, while the higher layers, and the part which lay furthest upstream, were fresh-water deposits at the mouth of the Carron; similarly with the present-day river, the delta, formed partly at the expense of the earlier one, lies on the average two or three feet above high-water mark, and the tides do not penetrate more than a quarter of a mile upstream from the river mouth, so that the highest layers of the delta are properly fresh-water deposits. The 50-ft. beach rises to 62 ft. about a third of a mile east of the railway, but beyond this point the surface becomes broken and the beach merges into a tract of irregular gravel mounds, separated by hollows without outlet, indicating the proximity of the tongue of a valley glacier.

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South of the viaduct across the Kyle at Culrain the 50-ft. beach must have been chiefly formed out of materials brought by marginal and other streams, and deposited here at the foot of the Oykell Valley glacier. The fluvioglacial origin is also indicated by the presence of two or three kettle-holes, close to Culrain Station, in the otherwise flat-topped beach. Before the sea sank below the 50-ft. level, the ice had retreated at least as far as Inveran, for the raised beach, though mostly forming a narrow fringe with broader expanses near Inverhouse, still makes a well-defined flat, with a large kettle-hole near the sharp bend of the road east of Rheantaoir. West of this, however, the terrace breaks up into hollows and mounds, the latter not rising higher than the level of the beach until beyond Rhelonie, where all trace of the terrace feature finally disappears.

There is some indication of a glacial overflow channel which, entering the wood south of Rheantaoir just below the 100-ft. contour, utilised and partly deepened the gorge leading eastwards to Inverhouse. The broad spread of 50-ft. beach at this point, already referred to, may be largely formed out of materials brought through this channel into tidal waters, at a time when the ice-foot lay between Inveran and Rheantaoir.

SUTHERLAND.

Messrs. Read and Haldane report that in the ground surveyed by them between the Kyle of Sutherland and Strath Fleet, the country rock consists of siliceous granulites in which occur granite masses and subordinate igneous rocks of various kinds.

Schists.—In type, the Moine rocks are very uniform throughout; they are white or pinkish siliceous granulites, in which what appear to be relics of felspar pebbles are occasionally seen. Narrow bands of a semi-pelitic nature are of rare occurrence. At a few places, lenses and small bosses of dark hornblendic rock have been found. These are usually schistose, but are occasionally rather massive, and are presumably of igneous origin. Throughout its extent, the siliceous granulite is traversed by great numbers of acid stringers, veins, and small dykes, which form intricate complexes. About a mile S.W. of Achany Lodge a prominent knoll, consisting of white vein quartz much crushed and broken, rises out of the surrounding peat flat; a similar smaller knoll occurs some distance to the south-east.

Granites.—In the Migdale area and northwards by Loch a' Ghobhair and Loch an Lagain, Mr. Read has mapped a large mass of granite, which forms the crags of Migdale Rock, Craig a' Bhealaich and Creag a' Ghobhair, and covers an area of about six square miles. It is a non-foliated, fine-grained whitish rock with a small amount of biotite. On Migdale Rock, the granite is traversed by numerous contemporaneous pegmatites of an average width of 1 in. These seem to have been formed by exudation of the last juices of the granite magma into early

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joint planes in the already solid normal rock. The direction of the joints is N. 10 E—S. 10 W. Later still seem to be narrow quartz veins which run N. 10 W.—S. 10 E.; these later veins have occasionally pegmatite at their margins and quartz at their centres.

On its western and southern margins the Migdale Granite has a sharp junction with the Moine granulites; the granite is welded to the foliation planes of the granulite, which is little altered, possibly because it had already reached so high a degree of mineral stability. On the eastern and northern margin, however, no definite line can be drawn for the junction, for here a thorough complex of granite apophyses and granulite is found, which forms a belt half a mile or so in width outside the solid granite.

At Beinn Donuill, 5 miles N.E. of Bonar Bridge, a basic margin to the granite is seen. In parts the basic mass is composed of a very coarse black hornblende-biotite-rock of a scyelitic nature; with this are associated hornblende-biotite-rocks with patches of pink felspar; other types show approaches to granite. There is here little doubt that the scyelite and associated hybrid rocks belong to the Migdale Granite intrusion. The importance of this fact will be seen immediately in the discussion of the Ach'uaine hybrid rocks.

Part of the Lairg-Rogart Granite falls within the area surveyed. Mr. Haldane notes that in the Fleet valley the rock is an unfoliated coarse-textured biotite-granite, with occasional patches of dark basic material. This granite passes eastwards into the somewhat paler type seen at Dalmore.[1] This intrusion is separated from the Moine granulites by a well-marked belt of crush with a N.W.—S.E. direction which has determined the course of the Fleet valley at Acheille.

Rocks probably of hybrid origin.—At Ach'uaine (Gælic—green field), 2½ miles N.N.E. of Bonar Bridge, the vivid green herbage of the fields makes a striking contrast to the heather-clad ground occupied by the siliceous granulites and Migdale Granite. On examination, Mr. Read finds this to be due to the occurrence of ultrabasic and associated rocks at this locality. These rocks form a series of detached, elongated, irregular masses on the ground around Ach'uaine and Ledsaurich. They have also been met with further north around Cnoc a' Choire Bhuidhe by Mr. Haldane. From Ach'uaine a broken belt runs north for nearly a mile to Asdale. Near Ledsaurich another belt runs for about a mile with an average width of 100 yds.

Until a thorough microscopic examination of these rocks has been made, little beyond the impressions formed in the field can be given. The rocks of these basic masses are regarded as mixed rocks formed from two types, an ultrabasic scyelite type and a granite type resembling the Migdale granite. The

[1] *Vide* 'Summary of Progress for 1909' (*Mem. Geol. Surv.*), 1910, p. 41.

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scyelite is a hornblende-biotite-rock with large plates of black mica often 2 cms. across; the granite is a pinkish very fine-grained rock with scarce and small biotites. It is considered that, by the mixture of these two types, sometimes as magmas, sometimes by incorporation of ultrabasic in acid magma, sometimes by penetration of almost solid ultrabasic material by acid magma, there have been produced the innumerable varieties of mixed rocks seen in these masses. Some of these mixed types are :—

(1) Hornblende-biotite-rock with large patches of pink felspar.

(2) Finer grained rocks of similar composition to (1).

(3) Streaky rocks formed by inclusion of hornblende-biotite-rock in a granite base.

(4) Purplish ' acidic ' types with large plates of biotite.

(5) Innumerable mixtures formed by the intrusion of granite into scyelite without assimilation.

Mr. Dinham has found what appear to be rocks related to those just described at a locality 150 yds. south of the top of Lamentation Hill in Ross-shire.

Lamprophyres.—Mr. Haldane has recorded a lamprophyre dyke on the summit of Sithean Mor, 1 mile east of Invershin. This dyke trends almost due east-and-west and can be traced for over a quarter of a mile, and is possibly the continuation of that noted by Mr. Dinham on Lamentation Hill in Ross-shire (*see* above, p. 44). It cannot be traced far east of Sithean Mor. It is a quite unfoliated dark massive rock with abundant large plates of black mica. It contains many inclusions of Moine granulite and of granite (Migdale Granite?), which stand out as knobs on the weathered surfaces. Similar lamprophyre dykes have been found by Mr. Read at Creagan Reamhar, Garbh Leathad, Allt na Feith Moire and Allt na h' Atha. That these lamprophyres are later than the Migdale Granite has been proved by Mr. Read's discovery of a lamprophyre dyke cutting the granite at Loch Leisgin.

Old Red Sandstone.—At the eastern edge of Sheet 102 and south of Strath Fleet a small faulted-in patch of flaggy red sandstone has been noted by Mr. Haldane. Granite occurs both to the north and to the south of this patch but no actual boundaries are seen. The sandstone dips at 30° to the south-east, and is probably the termination of the Old Red Sandstone belt shown in Sheet 103, which may be here cut out by the large N.W.–S.E. fault already mentioned as occurring in the Fleet valley.

Pleistocene and Recent.—On the north-east shore of the Kyle of Sutherland, between Bonar Bridge and Linsidemore, there is a well-marked 50-ft. beach which, when traced up the Oykell valley, displays features similar to those described above by

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Mr. Dinham for the beach on the south-west side of the Kyle. There are also traces of a lower shelf at about 25 ft.

Coalfield Revision.

3. North Ayrshire Coalfield.

Field-work was mainly carried on in the volcanic district of Sheet 22. Mr. Anderson was engaged in the completion of coalfield maps commenced by the late Mr. C. T. Clough and himself. A boring for coal was visited near Rankinstone, and replies were furnished to enquiries from colliery managers entailing field observations in the Troon and Dalmellington districts.

The revision of the Calciferous lavas of the Clyde plateau has been continued by Mr. Richey and Mr. Burnett in the hill country between Stewarton and Mearns. Chief interest centres in a great spread of trachytes,[1] of which 8 square miles have now been mapped. It is probable that most of these trachytes are lava flows, though this conclusion is based on somewhat sparse observation of vesicular tops, unchilled margins, and intercalated beds of tuff. The stratigraphy of the area is especially difficult to work out, as the country is of low relief, with scarp-featuring ill developed; added to this there is extensive faulting and also an original discontinuity of the various lava zones, some of which were referred to in last year's 'Summary of Progress.' It can, however, be definitely stated that the widespread top Dalmeny Group of last year's classification continues eastwards through the uplands north of Fenwick, and is underlain by trachytes, to some extent associated with mugearite and various types of basalt, and that this assemblage is in turn underlain by a thick group of macroporphyritic basalt lavas. Considerable areas of trachyte occurring to the east of the Mearns–Fenwick road appear to be overlying the continuation of what is elsewhere the top group of Dalmeny basalts, but their mapping is incomplete. In this connection it may be mentioned that evidence of an acid phase posterior to the Dalmeny Group is afforded in other parts of North Ayrshire by the occurrence of abundant felsitic pebbles in the volcanic detrital beds that form the base of the Calciferous Sandstone sediments overlying the lavas.

4. Stirlingshire and Clackmannanshire.

The revision of the Stirling and Clackmannan area of Carboniferous rocks was continued during the spring and autumn by Messrs. Dinham, Read and Haldane, and that of the Douglas area by Mr. Macgregor. In addition to the normal field work short visits were paid to different localities in connection with

[1] J. E. Richey, 'Summary of Progress for 1919' (*Mem. Geol. Surv.*), 1920, p. 27.

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various 6-in. maps of the Central coalfield in course of publication. Borings for coal and ironstone in the districts of Barrhead, Glasgow, Airth, Bo'ness and Douglas were also examined during the course of the year.

STIRLINGSHIRE.

Mr. Dinham, in continuation of his work on the Lower Limestones on the north side of the Central coalfield.[1] began a re-examination of certain critical sections in the Corrie Burn district in 1-in. Sheet 31. The discovery in the middle burn of a representative of the "sandy encrinital limestone of Campsie," which occurs between the Hurlet and the Blackhall Limestones, is worth recording. This bed had previously been discovered in the Shields and Bannock burns,[2] but had not been recognised at Corrie, which lies between them, doubtless owing to the fact that the limestone is everywhere decalcified and resembles an ochreous sandstone. Its position in the Corrie sequence is shown in the following table :—

	Ft.	in.
Gap	–	–
Sandy LIMESTONE with occasional encrinites, &c.; the bottom 15 in. consists of thin beds very full of various marine fossils. Thickness apparently about	6	–
Gap about	5	–
Faky blaes	1	–
Sandstone, flaggy false-bedded	1	6
Sandstone, thin bedded and colour-striped	2	–
Gap	5	–
HURLET LIMESTONE seen here	7	–

The decalcified limestone is seen again 100 ft. further to S.W., at the east corner of an old quarry in the Hurlet Limestone.

In 1-in. Sheet 39 Mr. Dinham was engaged on the survey of the ground lying south and east of Stirling. The chief points of interest in the surface geology are :—

(i) The discovery at Craig Moss, 3 miles S.E. of the town, of a hitherto unmapped 'islet' of rock in the middle of the Carse flats. (ii) The presence of large erratics of Highland grits of Ben Ledi type, and of Old Red Sandstone conglomerate, on the slopes of Dunmore Hill. (iii) The tracing of the old coast line of the '100-ft.' raised beach. The inner margin of this beach appears to rise to at least 145 ft. above O.D., and is fringed by terraces of sand and gravel which at Cambusbarron attain a thickness of at least 50 ft. Around Carnock and Castleton the old coast line crosses the outcrop of the massive sandstones of the Millstone Grit. These now form conspicuous lines of crags

[1] 'Summary of Progress for 1919' (*Mem. Geol. Surv.*), 1920, pp. 34-41.
[2] *Ibid.*, p. 38.

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—a phenomenon rare in the Millstone Grit of Scotland, and due in this instance to the removal of the usual boulder-clay cover by the waves of the old sea, on whose shore they projected as rocky reefs and islands. The sudden disappearance of these crags as the old coast line is followed towards the north-west, coincides with an abrupt passage, across a large fault, from Millstone Grit into strata of the Upper Limestone Group, in which sandstones are neither as thick nor as numerous. This fault has also been approached from the north side in the workings of Carnock Pits; its throw amounts to at least 200 fms., and it is probably a continuation of the big Campsie Fault, which separates the coalfields of South Stirlingshire from the lavas of the Kilsyth Hills.

CLACKMANNANSHIRE.

Coal Measures and Millstone Grit.

Mr. Read has begun the revision of the Alva, Menstrie and Alloa districts of the Clackmannanshire coalfield. A general section of this coalfield is given in one of the published sheets of vertical sections (Sect. 4, Sheet 5, Scotland, 1877). It illustrates the ground immediately adjoining Devon Ironworks (now Devon Colliery) about 1 mile south-east of Alva, and shows at the top 72 ft. of red sandstone assigned to the Barren Red Measures. These beds are seen in the quarries around Devon Colliery, in the railway cutting near Black Row, and probably also in the Silver Glen, 500 yds. east of Alva Church. They are coarse reddish false-bedded sandstones and occupy the centre of the northernmost basin of the Clackmannan field. Their correlation with the Barren Red Measures is still open to doubt since sandstones of very similar type occur in this district within the limits of the Productive Coal Measures.

Abandoned shafts of which no records exist are very common in the Clackmannanshire field, coals and ironstones, both clayband and blackband, having been wrought here from an early period. Some of the workings must be at least 125 years old; the clayband ribs above the Nine-Foot coal, for example, were mined for the long-abandoned Devon Ironworks (*circa* 1792–1856).

The Devon basin is limited on the north by the Ochil Fault. Good sections are seen in the Alva, Silver, Mill and Kirk burns, which drain the face of the Ochils, and these enable the position of the fault to be fixed with some accuracy. In Alva Glen, Lower Old Red volcanic rocks are brought against smashed and upturned red sandstones of Carboniferous age. In the Silver Glen, the red sandstones already mentioned are seen to overlie white sandstone, blaes and fakes with thin coals dipping steeply south off the fault. Between the volcanic rocks and the Carboniferous sediments there is a dolerite intrusion which presents chilled edges to the volcanic rocks, and is crushed on its south side against the Carboniferous. In the Mill Burn, blaes, fakes

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and sandstone are almost vertical against the fault. A dolerite intrusion is found between the volcanic rocks and the Carboniferous, but here it appears to have chilled margins on both sides. In the Kirk Burn again the dolerite shows a chilled margin against the volcanics while it is smashed and broken along its junction with the sediments. It seems probable, therefore, that there has been repeated movement along the line of the Ochil Fault. It is still a notable line for earthquake tremors.

Along the western side of the basin, at the margin of the 50-ft. terrace on the south side of the River Devon and east of Tullibody Bridge, coarse white friable sandstones occur, which are referable to the Millstone Grit Series. This view is confirmed by the fact that in Tullibody Mine, at the north end of Gunther's Wood, the Coalsnaughton Main Coal, lying near the base of the Coal Measures, was formerly wrought at the outcrop. Bores on Knowfaulds and on the ground east of Tullibody show that there also Millstone Grit strata are present at the surface.

Mr. Haldane has extended the revision of the Clackmannanshire coalfield to the Clackmannan and Kincardine-on-Forth districts. Part of the ground is occupied by much faulted strata of Coal Measures age, to the east of which the Millstone Grit forms the higher ground of Tulliallan Forest and Bath Moor. The only stream of importance in this area is the Black Devon and, apart from the numerous partial sections seen along its course, natural rock exposures are few. The Cherry and Splint Coals, with their associated strata, are seen in the Devon 400 yds. west of Mary Bridge to the north-west of Clackmannan, while the Coalsnaughton Main is exposed where the river flows along the north of Birkhill Wood, 2 miles north-east of the same town. The district contains very many old workings, of most of which no records can now be traced. Of the numerous disused sandstone quarries the one at Craigrie, a mile south-west of Clackmannan, is the most interesting, as it furnishes an excellent section of the Nine-Foot Coal. The details of this section are :—

	Ft.	in.
Grey fakes	6	–
Black blaes	–	6
COAL	–	8
Fakes	–	6
Coaly rib	–	1
Fakes with clayband nodules	–	8
Sandstone	–	4
Clayband ironstone	–	1
Sandy fireclay	–	3
Flaggy sandstone and fakes	4	6
Blaes with thin clayband ribs and nodules	1	11
,, ,, ,, ,, "mussels"	1	7
Black blaes with fish remains	–	3
NINE-FOOT COAL, with 4-in. of parrot on top	9	–
Fakes	1	–
Massive, yellowish-white sandstone - At least	25	–

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Glacial and Recent.

Outside the limits of the 100-ft. raised beach the ground is covered by a thick mantle of boulder clay containing many boulders derived from the Ochil Hills and from the Highlands to the north-west (*cf.* above, p. 49). Striae observed on the volcanic rocks of the Ochils indicate a south-easterly ice-flow, but the marked east-and-west orientation of the drumlins near Clackmannan shows that there the movement was in conformity with the general movement of the ice through the Central Valley.

Around Alloa the 100-ft. beach is well developed. Its margin has now been traced, generally as a well-marked feature, from Tullibody to Kincardine-on-Forth. Its deposits are mainly sands and clays, and at Hilton Brick Works near Alloa, dark chocolate clay, 30 ft. thick, is being worked for the manufacture of bricks, sanitary ware, &c. Clays of the 100-ft. beach were also formerly wrought to the north of Clackmannan.

The River Devon, below Tillicoultry, meanders through the flat 50-ft. carse lands, composed of a stiff brown clay. Upon the carse well-marked deltaic cones have been formed by streams issuing from the Ochil Hills, and on these the villages are built. Where the Black Devon traverses the deposits of the 50-ft. beach to the south-east of Alloa, small specimens of *Cardium* and of *Mytilus* have been obtained from a shell-bed in some of the blue clays. This beach has been more or less distinctly followed as far as Kincardine.

A deep buried channel runs up the Devon valley between Menstrie and Tillicoultry, as described in Mr. H. M. Cadell's 'Story of the Forth' (Glasgow, 1913, p. 90). A boring at Glenochil Distillery, Menstrie, passed through 337 feet of surface deposits, and did not reach rockhead. The height of the surface at this locality is only 35 or 40 feet above O.D.

LANARKSHIRE.

In the Douglas Coalfield, Mr. Macgregor and Mr. Manson examined and measured a number of sections in the Carboniferous Limestone Series at Bankend. The Poneil Water at this locality, along with its tributary the Hagshaw Burn, furnishes a fairly complete sequence from the Index Limestone to the Ell Coal and from the Macdonald Coal down to the well-known *Productus giganteus* limestone near the top of the Calciferous Sandstone sediments. A large suite of fossils has been collected from the various members of the Lower Limestone Group, but pending detailed examination of this material their correlation is held over.

As a supplement to the short account of the Douglas coalfield given in the 'Summary of Progress for 1919' (pp. 31–4,) the sections of the Limestone Coal Group exposed in the Hagshaw Burn may be shortly summarised. The Index Limestone, formerly exposed near the mouth of the burn, can no longer be examined

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in situ, but loose rocks that remain resemble the exposure in the old quarry at Longhill Burn some 2 miles to the east. The section of the Smithy and Dross Coals, and of the strata below and above them, is as follows :—

	Ft.	in.
Faky sandstone	3	–
Coal	–	7½
Fireclay	1	–
Blaes	1	6
Parroty blaes	2	–
Coal	–	6
Coaly fireclay	–	6
Faky sandstone with rooty top	9	6
Sandstone and faky sandstone	6	11½
Fakes and faky blaes	2	3
Firm blaes	3	3
Soft dark blaes	1	3
Firm blaes	3	3
Smithy Coal	2	3
Dark fireclay	1	4½
Coal	–	4
'Horn' or Wild Gas Coal	–	6
Dross Coal	3	10
Sandy fireclay	–	10
White rooty sandstone with irregular ribs of blaes	3	9
Blaes	1	–
Parroty blaes	1	3
Blaes	2	11
Faky sandstone	–	8
Blaes	3	5
Irony 'kingle' (*i.e.*, hard sandstone) lenticular up to	–	6
Blaes	1	6

The details of the section of the Ell Coal are :—

		Ft.	in.
Sandstone roof		–	–
Ell Coal	Head Coal	2	9
	Dark fireclay	1	6
	Coal	1	–
	'Horn' or Wild Gas Coal	–	11
	Coal	1	7
White rooty ganister-like sandstone floor.			

No exposures of the Nine-Foot or Six-Foot Coals occur in the Hagshaw Burn, but it should be noted that there is a narrow troubled area to the south of the fault which cuts off the coals noted above at a point about 450 yds. from the junction with the Poneil Water. It is not yet certain in what part of the sequence these troubled beds lie. They are followed up-stream by a very

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fine exposure of the Macdonald Coal. The details of the section are :—

	Ft.	in.
Dark blaes with clayband nodules and ribs; *Lingula* predominant, some brachiopods	–	–
Clayband rib - - - - - - 2½ in to	–	4
Dark shelly blaes, with brachiopods, &c. - -	1	6
Layer of flattened shelly nodules of irony limestone	–	2
Dark shelly blaes - - - - - - -	2	9½
Dark blaes, very shelly - - - - - -	1	9
Limestone rib - - - - - - -	–	7
Dark blaes, very shelly - - - - - -	1	8
Macdonald Coal { Coal - - - - - -	2	–
Macdonald Coal { Dark Fireclay - - - -	–	4
Macdonald Coal { Coal - - - - - -	2	10
Fireclay and balls - - - - - -	3	2
Dark parroty blaes with *Lingula* - - - -	1	–
Faky sandstone - - - - - 1½ ft. to	3	–
Blaes and hard fake ribs - - - - -	8	6
Fakes, faky sandstone and blaes - - at least	13	6½

There is a break in the sequence here but the Top Macdonald Limestone is not far below the base of the section just quoted. The marine beds overlying the Macdonald Coal, and the Lingula band which occurs a few feet below it, are very useful horizons in identifying the seam in the workings. Another exposure of the Macdonald Coal is seen in the Poneil Water nearly five-sixths of a mile east of the ford at Brockley; here it shows :—

	Ft.	in.
Shelly blaes (several feet thick) - - - - -	–	–
Coal - - - - - - - - - -	1	6
Fireclay - - - - - - - - -	1	0
Coal - - - - - - - - - -	–	7
Fireclay - - - - - - - - -	–	8
Coal - - - - - - - - - -	–	7½
Fireclay - - - - - - - - -	3	6

The attenuation of the seam in an easterly direction is also a characteristic of all the higher coals; on the eastern margin of the Douglas-Ponfeigh coalfield, however, they appear in still thicker development.[1]

The Macdonald Limestones are exposed at several localities and from the blaes associated with the highest of these *Posidonomya corrugata* has been obtained. The Hawthorn or Main Limestone is also seen at various places in the Poneil Water and Hagshaw Burn, and shows 6 or 7 fathoms of very fossiliferous nodular limestones and limy fakes, containing *Lithostrotion* bands, large *Producti* and corals. A 6-in. or 7-in. coal underlies it, while above it are 4½ ft. of faky sandstone and 2 ft. of a very white ganister-like sandstone with a nodular top. This sandstone

[1] 'Summary of Progress for 1919' (*Mem. Geol. Surv.*), 1920, p. 33.

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forms an exceedingly useful index in working out the details of the various partial sections. On top of it occurs a lenticular sandy ironstone, apparently worked in former days. This band reaches a thickness of 8 in. but is often absent; above it comes a slaty pyritous rib about ½ in. thick containing fish remains, and forming the base of a thick series of dark crumbling fossiliferous blaes.

5. Borings for Oil at D'Arcy and West Calder.

Periodical visits to the experimental borings for oil have been continued and the samples of sediments and pieces of rock have been examined by Mr. Tait.

D'Arcy Oil Well (1-in. Sheet 32 Scotland, 6-in. Sheet, Edinburgh, VIII., S.E.).—This boring, situated about 1 mile S.S.W. of the mining village of Chesterhill (3 miles S.E. of Dalkeith) commences in the Lower Limestone Group where it rises in a clearly defined anticline that forms a local fold along the general anticlinal uplift between the Roman Camp and Cousland on the eastern side of the Midlothian Coal Basin. South of the boring the anticline is crossed by a fault and several others have been proved in colliery workings both to the east and west of the local anticline.

The boring commences a few feet below the outcrop of the D'Arcy Limestone (No. 2 or Skateraw Limestone), the outcrop workings forming a semicircle round the site of the boring. At a depth of 27 fathoms it passes through limestone beds containing marine shells interbedded with sandstones and then continues in an alternating series of shales, sandstones, fireclays and marls to a depth of 117 fathoms. At 118 fathoms there occurs an oil-shale, approximately 15 ft. thick, and resting on a sandstone that gives off a large quantity of gas. The commercial value of the oil-shale cannot be estimated from the samples obtained by the method of drilling, but there is little doubt that it is one of the bands towards the top of the Oil Shale Group.

From 118 fms. to 150 fms.—the present depth of the boring—the strata are mainly sandstones, with a band of white limestone, 10 ft. thick at 126 fms. Traces of a coal occur at 139 fms. At 150 fms. a fine-grained white sandstone yields brackish water with traces of oil.

West Calder Oil Well.—In the 'Summary of Progress for 1919' an account of this boring was given to a depth of 543 fms. The present depth is 651 fms., the strata between 543 fms. and 650 fms., consisting of black shales with interbedded bands of volcanic ash. The boring is now in sandstone yielding salt water in considerable quantity. The absence of sandstones between 215 and 650 fms. is remarkable and it would appear that sandstones of the Granton Sandstone Group have not yet been reached.

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III.—PETROGRAPHICAL WORK.

1. England and Wales.

As far as England and Wales are concerned most of the petrographical work has been in connection with special enquiries from private individuals and Government departments. An investigation into the size and nature of dust-particles aspirated from the air of mines and factories has been carried out at the request of the Home Office, and the results will be in due course embodied in the reports of that department. Dr. Thomas at the invitation of the Society of Antiquaries has investigated the probable source of the 34 foreign stones that constitute all that remains of the inner circle and inner horse-shoe of Stonehenge. These stones have come within the purview of many geologists, who have suggested in general terms possible sources in North and South Wales, Devon, Cornwall, and even Scotland. They were simple standing-stones, not capped by lintels, and show no signs, except in the case of one prostrate stone, of ever having been morticed, as are the sarsens of the outer circle and the trilithons. That they were dressed on the spot and considerably reduced in size has been abundantly proved by the copious fragments found in the soil during the recent excavations by H.M. Office of Works.

The most interesting feature of these stones is that of the 34 now remaining, 29 are all of the same type (blue stones) and are formed of a bluish green even textured diabase that is characterised by an abundance of irregular felspar crystals (albite oligoclase) that appear in the hand-specimen as pinkish or white spots ranging from the size of a pea to that of a hazel nut.

This spotted character, not commented upon by earlier observers, at once removes the rock in question from the generality of diabases, and renders the identification of the source a matter of greater certainty.

A spotted diabase of identical appearance, mineralogical composition and microscopic character is the dominant rock of the Prescelly Mountains in Pembrokeshire. These hills rise more or less abruptly from the plain of Western Wales and owe their form and preservation largely to the sills of diabase which extend through them from Rosebush on the west to Crymmych on the east.

Such spotted diabases are, as far as Great Britain is concerned, practically restricted to the Pembrokeshire area and therefore the Prescelly Mountains must be regarded as the most probable ultimate source of the Stonehenge ' blue stones.'

It is interesting to note that in association with the spotted diabase of Prescelly there occurs a considerable mass of banded and minutely spherulitic rhyolites. These rocks, grey in colour and weathering with a white crust in which the banding shows most clearly, are identical with three stones of finely-banded

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rhyolite represented amongst the foreign stones of Stonehenge. It, therefore, appears that 32 out of the 34 foreign stones may, with little doubt, be referred to Pembrokeshire sources. The remaining examples of slaty sedimentary rocks and the micaceous sandstone of the so-called 'altar stone' are not in disagreement with a Welsh derivation.

As far as Salisbury Plain is concerned the foreign origin of these stones is unquestionable, and various theories have been propounded to explain their presence in a region so remote from all possible sources. The theory most generally accepted and first put forward by the late Prof. Judd, was to the effect that they had been transported by ice to the Plain from some region to the north; and he explained the absence of all smaller stones of the same character by assuming that these had been utilised for mill-stones, gate-posts, &c. As pointed out by Mr. Stevens and other workers, there is no evidence of the existence of any masses of rock of these types, either large or small, in Wiltshire, except within the area of Stonehenge itself. Further, the ice that was supposed to carry these boulders to Salisbury Plain would have had to select carefully from all the rocks over which it passed, not only as regards rock-type, but also as regards the size of the transported material. The idea that such rocks had been glacially carried to the Plain must be dismissed as being contrary to the mass of geological evidence. With the object of eliminating all other possible sources, especially those of a proximate nature, a careful revision was made of the rock-types represented amongst the large boulders stranded on the coastal regions of Hampshire between Selsey and Bournemouth. All specimens available including those noted by Godwin Austin, Clement Reid, Osborne White, and others, have been examined, with the result that in no case has a Stonehenge type been detected. We may assume, therefore, that these boulders, often of considerable size and occurring relatively near to Salisbury Plain were either unknown to, or disregarded by, the builders of Stonehenge. In view of the last-mentioned fact and the still more important uniformity of type presented by the Stonehenge 'blue stones' and rhyolites, the inevitable conclusion is that the stones were brought direct from their parent source by human agency.

In Pembrokeshire, boulders of these rocks, dislodged by the ice that passed over the Prescelly Mountains, lie scattered over the stopes and low ground to the south and south-east, and masses of suitable size could be easily collected. That the monoliths were derived from a glaciated region, a feature that at once rules out Devon and Cornwall as possible sources, is indicated by the recent find at Stonehenge of a large flake from one of the 'bluestones,' which shows good glacial striations.

2. Scotland.

Petrographical work in connection with the forthcoming memoir on the Island of Mull has been carried out by Dr. Thomas

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and Mr. E. B. Bailey. Special attention has been paid to the classification of the basalt lavas of Sheet 44. It has been found that they are roughly divisible into two petrographical groups olivine-rich and olivine-poor respectively. Of these, varieties rich in olivine preponderate in the lower part of the volcanic pile, and the olivine-poor varieties in the upper part.

In the Ben More region the group rich in olivine is roughly 3,000 ft. in thickness, and it is clear in the field that the group poor in olivine which succeeds is of approximately the same magnitude.

In previous reports the basalts poor in olivine have been spoken of as andesites, and this appellation has not infrequently been applied to certain olivine-rich varieties that have a pale tint in the hand-specimen. The prevalence of pale lavas associated with, but distant from, the mugearite lava-zone of Ben More was, perhaps, first recognised by Sir Archibald Geikie. The pale colour is now shown to be correlated with a poor development of magnetite which results from the decomposition of olivine. In the Ben More region it would seem that the olivine of the lavas in the lower part of the olivine-rich group of basalts was more ferruginous than that of lavas on higher horizons, for it yielded on decomposition abundant secondary magnetite. It is one of the most interesting features of Mull geology that within a circle 14 miles in diameter, none of the basalt lavas have retained their olivine in a fresh condition. This circle centres on the hill-country between Glen Cannel and Glen More, and includes Ben More well within its circumference. The definite character of this phenomenon will be recognised when it is said that out of 336 olivine basalts sliced from within the circle none has retained any fresh olivine, while of 44 specimens of similar rocks sliced from outside the area in question, 34 carry this susceptible mineral in a more or less unaltered condition.

Side by side with this replacement of olivine by chlorite and serpentine, there is a widespread development of albite and epidote filling cracks and vesicles. These phenomena are attributed to pneumatolitic action connected with the Mull centre of activity. A full discussion must be deferred until the publication of the Memoir, but it is proper to say that many of the features have already been dealt with in the writings of the late Prof. Judd.

IV.—CHEMICAL WORK.

During the year work in connection with the Special Report on British Refractory Materials has been continued, and 18 fireclay analyses completed for inclusion therein.

In addition, analyses were made of one rock from Leicestershire for Memoir Sheet 169 and of eight from Aberdeen and Banffshire for Memoir on Sheets 86 and 96, the details of seven being included in this Report.

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As examples of the composition of British fireclays analyses of six are given below :—

Old Mine fireclay, black, Stourbridge.—One-in. Ordnance map (New Ser.), 167; 6-in. Staffordshire, 71, S.W. Museum No. 4354; Lab. No. 610.

Old Mine fireclay, white, Stourbridge.—One-in. Ordnance map (New Ser.), 167; 6-in. Staffordshire, 71, S.W. Museum No. 4355; Lab. No. 611.

Fireclay, No. 1 New Mine, Stourbridge.—One-in. Ordnance map (New Ser.), 167; 6-in. Staffordshire, 71, S.W. Museum No. 4357; Lab. No. 613.

Fireclay, No. 4 New Mine, Stourbridge.—One-in. Ordnance map (New Ser.), 167; 6-in. Staffordshire, 71, S.W. Museum No. 4356; Lab. No. 612.

'*Nonsuch Fire-earth*'—brown-green variety, Reading Beds, Epsom.—One-in. Ordnance map (New Ser.), 286; 6-in. Surrey, 19, N.W. Museum No. 5703; Lab. No. 653.

'*Nonsuch Fire-earth*'—'white' variety, Reading Beds, Epsom.—One-in. Ordnance map (New Ser.), 286; 6-in. Surrey, 19, N.W. Museum No. 5709; Lab. No. 659.

Lab. No.	610	611	613	612
SiO_2	45·22	77·71	58·18	62·67
TiO_2	1·08	1·38	1·27	1·15
Al_2O_3	31.32	13·46	26·36	22·30
Fe_2O_3	1·76	1·04	1·61	2·90
MnO	·03	·02	·03	·03
CaO	·34	·05	·29	·23
MgO	·51	·23	·69	·66
K_2O	·94	·06	1·67	·48
Na_2O	·23	·35	·20	·38
Li_2O	trace	trace	trace	trace
H_2O at 105° C.	3·00	·91	1·56	1·61
H_2O above 105° C.	11·30	4·81	8·19	7·86
P_2O_5	·07	·05	·12	·07
FeS_2	·01	·05	·04	·02
Organic matter	4·18	·12	·21	·12
CO_2	·04	·03	·01	·04
Total	100·03	100·27	100·43	100·52
Loss on ignition	18·52	5·94	10·17	9·58

Lab. No.	653	659
SiO_2	85·65	91·30
TiO_2	·36	·35
Al_2O_3	5·44	3·77
Fe_2O_3	4·21	1·98
FeO	·23	·11
MnO	·03	·02
CaO	·40	·34

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Lab. No.	653	659
MgO	·65	·44
K_2O	1·19	·60
Na_2O	·10	·01
Li_2O	nt. fd.	nt. fd.
H_2O	1·98	1·32
P_2O_5	·05	·03
FeS_2	nt. fd.	nt. fd.
CO_2	nt. fd.	nt. fd.
Total	100·29	100·27

Results calculated on samples dried at 105° C.

The following are analyses of rocks of the Older Igneous Series of Portsoy and district :—

Pyroxenite.—Line of crags, inside west edge of Whitehill Plantation, 300 yds. W. by N. of Whitehill Farm; ¾ mile W. of Rothiemay Station. One-in. map, 86; 6-in. Aberdeen, 17, S.W. Slice No. S. 20363; Lab. No. 640.

Labradorite Rock.—Knob, just above high-water mark, 200 yds. W.S.W. of gasworks, Portsoy. One-in. map, 96; 6-in. Banff, 3, N.E. Slice No. S. 2213; Lab. No. 639.

Epidiorite.—Sea-cliff, 70 yds. W. of gasworks, Portsoy. One-in. map, 96; 6-in. Banff, 3, N.E. Slice No. S. 20364; Lab. No. 641.

Lab. No.	640	639	641
SiO_2	49·76	48·85	48·65
TiO_2	·11	·29	1·30
Al_2O_3	2·70	26·51	14·92
Fe_2O_3	2·56	1·28	1·31
Cr_2O_3	·34	nt. fd.	nt. fd.
V_2O_3	·07	nt. fd.	nt. fd.
FeO	4·26	·95	8·03
MnO	·17	·13	·11
(CoNi) O	nt. fd.	·03	nt. fd.
BaO	nt. fd.	·01	trace
CaO	15·56	12·19	8·79
MgO	22·03	1·64	8·92
K_2O	·18	·96	1·76
Na_2O	·10	3·64	2·56
Li_2O	nt. fd.	nt. fd.	nt. fd.
H_2O at 105° C.	·24	·25	·23
H_2O above 105° C.	1·85	1·57	1·26
P_2O_5	·05	·08	·17
FeS_2	nt. fd.	nt. fd.	nt. fd.
Fe_7S_8	nt. fd.	nt. fd.	1·07
CO_2	·05	1·96	·96
Total	100·03	100·34	100·04

Anal.—E. G. Radley.

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Below are four analyses of the Younger Igneous Series forming part of the Huntly Igneous Mass :—

Peridotite.—Quarry on east side of road, midway between Boghaugh and Broadlands, ⅓ mile N.E. of Broadlands, 3 miles W.N.W. of Huntly P.O. One-in. map, 86; 6-in. Aberdeen, 25, N.E. Slice No. S. 20360; Lab. No. 634.

Olivine Gabbro.—Right bank of River Deveron, 200 yds. N. of Cairnford Bridge, 2¾ miles W. by N. of Huntly P.O. One-in. map, 86; 6-in. Aberdeen, 25, N.E. Slice No. S. 19680; Lab. No. 635.

Troctolite.—Craighead Quarry, in wood N. of road, ⅓ mile E. of Cairnford Bridge, 2 miles W. of Huntly. One-in. map, 86; 6-in. Aberdeen, 25, N.E. Slice No. S. 20361; Lab. No. 636.

Norite.—Ladysmith Quarry, W. of Keillenknowes, 4 miles N.N.E. of Huntly. One-in. map, 86; 6-in. Aberdeen, 17, S.E. Slice No. S. 20362; Lab. No. 637.

Lab. No.	634	635	636	637
SiO_2	35·72	48·11	44·29	48·58
TiO_2	·36	·75	·09	3·44
Al_2O_3	10·99	17·86	25·26	13·82
Fe_2O_3	3·73	·43	·04	1·14
Cr_2O_3	·37	·13	·09	nt. fd.
V_2O_3	·09	·05	·03	nt. fd.
FeO	6·37	5·20	3·28	12·73
MnO	·06	·30	·25	·32
(CoNi) O	nt. fd.	nt. fd.	nt. fd.	nt. fd.
BaO	trace	nt. fd.	trace	nt. fd.
CaO	3·28	12·42	11·32	9·43
MgO	26·62	9·53	7·94	5·21
K_2O	·43	·64	·49	·76
Na_2O	·58	2·34	2·30	2·87
Li_2O	nt. fd.	nt. fd.	trace	nt. fd.
H_2O at 105° C.	·58	·14	·33	·05
H_2O above 105° C.	8·72	·84	2·57	·36
P_2O_5	·14	·07	·07	·64
FeS_2	·12	·11	·12	·08
Fe_7S_8	1·49	·68	·95	·38
CO_2	·38	·54	·83	·37
Total	100·03	100·14	100·25	100·18

Anal.—E. G. Radley.

Quartz-Diorite Porphyrite.—Elongated boss, unconformably overlain by Keuper Marl and drift. N.W. corner of Sapcote Quarry. One-inch map 169. Six-inch Leicester, 43 N.E. Slice No. E. 12011. Lab. No. 633.

SiO_2	61·84
TiO_2	·66

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Al_2O_3	15·51
Fe_2O_3	1·90
FeO	2·84
MnO	·08
(CoNi)O	nt. fd.
BaO	·02
CaO	5·03
MgO	3·22
K_2O	1·98
Na_2O	4·12
Li_2O	nt. fd.
H_2O at 105°C	·34
H_2O above 105°C	1·97
P_2O_5	·21
FeS_2	·10
CO_2	·52
Total	100·34

Anal.—E. G. Radley.

V.—PALÆONTOLOGICAL WORK.

1. England and Wales.

The collections of fossils have been enriched by some valuable donations. Miss C. A. Raisin presented a large collection of Jurassic Mollusca, formerly in the possession of the late W. H. Hudleston. The specimens are well localized and are of fine quality, while many of them are of special interest, since they serve to illustrate some of Hudleston's published work. Mr. G. W. Lamplugh presented his fine collection of sponges from the Upper Chalk of Yorkshire. This comprises many specimens suitable for museum exhibition, and a wealth of material for special study. A collection of 500 specimens of Mollusca from the Crag of Oakley was received from Mr. F. W. Harmer.

Dr. Kitchin and Mr. Pringle examined several sections in the Gault of different localities. At Copt Point, Folkestone, they searched for the horizon characterised by the *catillus*-fauna, which occurs in the Rostratus Beds of sandy facies in Wiltshire and the Isle of Wight. It was found to occupy a position at Folkestone near the base of Price's Bed XI., about 15 ft. above the top of Bed IX. In a temporary opening made in an old clay-pit at Long Crendon, in Buckinghamshire, the clay was found to be Upper Gault, showing an ochreous basement-bed almost identical in character with that seen in the case of the overlapping Upper Gault near Leighton Buzzard, which there rests upon the uppermost parts of the Lower Greensand. At Long Crendon, the basement-bed occupies a position less than 3 ft. above a Purbeck limestone.

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Visits were also made to Cambridge, to examine a section in the Cambridge Greensand and Gault, and to the Leighton Buzzard neighbourhood, to continue observations on the Gault and contiguous deposits, begun unofficially by Dr. Kitchin and Mr. Pringle. At the Norman Cement Co.'s large pit at Cambridge, some excavations had laid bare the Cambridge Greensand, which is rarely so well seen. The phosphate-bed was observed to rest upon an uneven and bored floor of unfossiliferous Gault. It was not possible to determine the exact horizon of this uppermost Gault, but it is highly probable from its lithological characters and the absence of fossils in it, that it corresponds with a level well above the base of Bed XI. of Folkestone. This is in agreement with the observations made by Prof. Fearnsides many years ago in the Barnwell pit. The amount of erosion to which the Gault was subjected at these localities was, therefore, less than in some other pits at one time opened along the outcrop, where the phosphate-bed contained some of the fossils of Bed IX. of Folkestone, in *remanié* condition.

Further collecting of fossils from the nodules of the Tardefurcata Bed, below the Interruptus Zone south of Leighton Buzzard, has added considerably to our knowledge of the fauna of that horizon, which is there well characterised by species of *Leymeriella*. The results of collecting from the phosphate-nodules in the sands immediately below the Gault at West Dereham, Norfolk, favour the view that at that locality the Tardefurcata Zone is present below the Interruptus Clay, as in Bedfordshire.

Mr. Pringle visited the sites of numerous borings during the year. The results of the borings at Bourne End, Marlow and Slough have been incorporated in the Memoir on the Water Supply of Buckinghamshire and Hertfordshire. Upwards of a dozen borings in Norfolk have given interesting geological information, which has not yet been made available for publication. Light has been thrown on the underground extension of the Jurassic formations in that county. A boring at North Ferriby, near Hull, has shown that the Red Chalk there rests upon a clay which belongs either to the basal part of the Kimmeridge Clay, or to the upper part of the Corallian Series. The results of Mr. Pringle's examination of the cores at a deep boring at Yate, Gloucestershire, are published herewith as an Appendix (p. 92).

A piece of core from the Keele Beds in a boring at Slang Lane, Wellington, submitted to Mr. Pringle for examination, yielded a new insect-wing. This has been described by Mr. H. Bolton as *Archimylacris pringlei* in a paper read before the Geological Society.

Good progress has been made in museum revision-work. Mr. Buckman has continued the re-naming of the Jurassic ammonites. Mr. Chatwin has carried out curatorial work on

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the collection of Tertiary Mollusca, and has devoted much tir to the important task of registration.

The following specimens in the Museum have been figure and described :—

In the Palæontographical Society's Volume for th Year 1918.

(Published 1920.)

A Monograph of the British Ordovician and Silurian Bellero phontacea. (Part 1.)

By Dr. F. R. Cowper Reed, M.A.

Sinuites anceps *Reed*, pl. i, figs. 1, 1a, 2, 2a, p. 5.
„ bilobatus (*J. de C. Sow.*), pl. i, figs. 8, 8a, b, p. 7.
„ elongatus (*Portl.*), pl. i, figs. 12, 12a, 13, 13a, p. 9.
„ semirugosus *Reed*, pl. ii, figs. 13, 14, 16, p. 13.
„ soudleyensis *Reed*, pl. ii, figs. 18, 18a, b; pl. iii, fig. 3, p. 13.
Oxydiscus acutus (*J. de C. Sow.*), pl. iv, figs. 1, 1a, b, 2, 2a, p. 19.
„ ? llanvirnensis (*Hicks*), pl. iv, figs. 10, 10a, 11, 11a, p. 22.
Cyrtolites nodosus (*Salt.*), pl. v, figs. 1, 1a-c, 2, 2a, b, p. 25.
„ „ *var.* llandoveriana *Reed*, pl. v, figs. 3, 3a, 4, p. 26.
Kokenospira lingualis (*Salt.*), pl. vi, fig. 16; pl. vii, figs. 1, 1a, b, p. 35.
Tetranota hippopus (*Salt.*), pl. viii, fig. 16, p. 43.

The Pliocene Mollusca of Great Britain. Volume ii., Part 1.

By Mr. F. W. Harmer, M.A.

Scala (Spiniscala) trevelyana (*Leach*), pl. xlviii, fig. 14, (2 views), p. 528.
„ (Lamelliscala) frondosa (*J. Sow.*), pl. xlviii, fig. 22, (2 views), p. 532.
Pyrgulina scalaris (*Philippi*), pl. xlix, fig. 43, (2 views), p. 577.
„ spiralis (*Montagu*), pl. xlix, fig. 44, (2 views), p. 578.
Alvania (Massotia) lactea (*Michaud*), pl. l, fig. 41, (2 views), p. 621.
„ (Galeodina) carinata (*Da Costa*), pl. l, fig. 44, (2 views), p. 620.
Manzonia costata (*Adams*), pl. l, fig. 48, (2 views), p. 624.

In the Quarterly Journal of the Geological Society Volume LXXVI.

By Dr. F. J. North.

Tylothyris laminosa (*M'Coy*), pl. xiii, fig. 16, p. 197.
Spirifer plicatosulcatus *North*, pl. xiii, figs. 17a, b, p. 193.

In the Geological Magazine, Volume LVII., 1920.

By Dr. F. R. Cowper Reed, M.A.

Homalonotus (Burmeisterella) elongatus (*Salt.*), p. 343.

In the Annals and Magazine of Natural History, Volume V.

By Dr. C. W. Andrews, F.R.S.

Patanemys bartonensis *Andrews*, text-fig. 2, p. 149.

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IN TYPE AMMONITES, VOLUME iii.

By MR. S. S. BUCKMAN.

Retenticeras retentum (*Simpson*), pl. clxvi, figs. 1, 2.
Pavloviceras bathyomphalum *S. Buckm.*, p. 18.
„ omphaloides (*J. Sow.*), p. 18, (2 specimens).

IN THE REPORT OF THE YORKSHIRE PHILOSOPHICAL SOCIETY, 1919.

British Fishes and Reptiles—Pliocene to Holocene.

By MR. ALFRED BELL.

Notidanus griseus ? *Cuv.*, pl. i, fig. 4, p. 9.
Acipenser toliapicus *Ag.*, p. 12.

IN THE ANNALES DE LA SOCIÉTÉ GÉOLOGIQUE DU NORD, LILLE, TOME XLIII.

By DR. P. PRUVOST.

Leaia salteriana *R. Jones*, pl. ii, figs. 1–3; text-fig. 2, p. 262.

2. SCOTLAND.

Fossils were collected from Carboniferous Rocks in the Central coalfield, and from Mesozoic areas in the island of Mull and Sutherlandshire.

The Carboniferous fossils were obtained partly from natural exposures and partly from borings. In several instances the determination in borings of important horizons, about which there was doubt, was successfully achieved from palæontological evidence.

A preliminary examination of fossils collected by Mr. Manson on the west coast of Mull has led to the recognition of Rhaetic, Hettangian, and Sinemurian strata referred to on p. 35.

Detailed collecting, on zonal lines, was made in the Jurassic rocks of the Brora district in Sutherland, but as the work was undertaken late in the year, the critical examination of the fossils could not be begun in time to be summarised here.

VI.—PHOTOGRAPHIC WORK.

In England and Wales 26 views of geological subjects have been added to the collections.

In Scotland 170 negatives of landscapes of special geological interest in the counties of Argyll, (Morvern and Mull), Forfar and Kincardine were obtained.

VII.—MUSEUM OF PRACTICAL GEOLOGY.

In illustration of Vol. VII. of the 'Special Reports,' a temporary exhibit has been prepared of the lignites, jets, Kimmeridge oil-shale, mineral oils and cannel coals of Great

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Britain. This exhibit, which includes a sample of the oil from the Hardstoft boring in Derbyshire, has been the object of much public interest.

Dr. J. Morrow Campbell lent a large suite of specimens in illustration of his paper on the Tungsten Deposits of Burma, and Mr. W. S. Lockhart has lent a Chinese screen, which is a very beautiful example of skilful artistic treatment of a colour-banded slate.

Although much work is still necessary before the Museum recovers from the disorganisation caused by the war, it has been possible this year to make all parts accessible, and the work of arrangement is now in progress.

List of Donations during the year 1920.

Acton, A., Esq.—Two nodules from sandy limestone shales, also sections and specimens of silica.

Anderson, Dr. Victor C.—Specimen of oil shale from Grand Valley, Colorado, with photographs.

Andrews, Charles T., Esq.—Specimens of phenakite crystals, also enhydros, from Brazil.

Barrow, Mrs. R.—A fine specimen of *Ammonite* from the Mammillatus Bed of West Dereham, Norfolk.

Bolckow, Vaughan & Co., Messrs.—A specimen of fused silica-brick, also akermanite crystals.

Brown, G. F., Esq.—A specimen of *Lima hoperi* Mant., from the Upper Chalk of Purley.

Buck, the Hon. E. C., M.Inst.C.E., F.G.S.—specimens of petroleum (pitch) from the Waini and Pomeroon districts, British Guiana.

Carley, G., Esq.—A fine group of pyrites crystals from the Gaurano Mine, Tuscany.

Carruthers, R. G., Esq., F.R.S.E.—Two specimens and a series of thin sections of *Cryptophyllum hibernicum* R. Carr., from the Carboniferous Limestone of Bundoran, Donegal Bay, Ireland.

Dewey, H., Esq., F.G.S.—Specimens of marcasite and pseudomorphs, also ancient slags.

Edge, Lieut. A. B.—A specimen of siliceous sinter, from Devonshire.

Garnett, C. S., Esq.—Two small specimens of red fluorspar from Ashover.

Gomme, A. T., Esq.—Part of a dermal spine of *Polacanthus*, from the Wealden of Cuckfield, Sussex.

Greenly, Dr. E.—A specimen of Asteroid from the Middle Calcareous Grit of Filey Brig, Yorkshire.

Hackney, Noel G., Esq., M.Inst.M.M.—A drawing of the Southampton Common Well, by Henry Penrose, Engineer, 1842, showing strata to 560 feet. Scale, 1 inch—4 feet.

Hall, T. Clifford, Esq., Assoc.M.Inst.M.M., F.G.S.—Minerals and rock specimens from Abyssinia; also specimen of tin vein from Roche, Cornwall.

Harmer, F. W., Esq., M.A., F.G.S.—A large series of Crag Mollusca from Oakley, Suffolk.

Holloway & Co., Ltd., Messrs. G. T.—Cobaltite from the Cloncurry district, Queensland, Australia.

Hooker, Lady.—Copper ore and graphite from Sikkim.

Kidner, N. W., Esq.—A fragment of upper jaw of the crocodilean genus *Steneosaurus*, from the Cornbrash near Thrapston.

King, W. B. R., Esq., M.A., F.G.S.—Seven specimens of *Griffithides shunnerensis* King, from the Millstone Grit of Shunner Fell Well, near Hawes, Yorkshire. Also 6 specimens of volcanic rocks from the Rhine valley.

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KITCHIN, F. L., ESQ., M.A., PH.D., AND PRINGLE, J., ESQ., F.G.S.—A series of fossils and rock-specimens from the Lower Greensand, Gault and Cenomanian of the Leighton Buzzard district.

LAMPLUGH, G. W., ESQ., F.R.S.—A large suite of fossils (mostly sponges) from the Upper Chalk of Yorkshire and a few fossils from the Red Chalk of Yorkshire.

LAVER, H. E., ESQ.—Two boxes of Chinese paints.

LEIGH, THE RIGHT. HON. LORD.—Specimens of pyrrhotite from Griqualand.

LIBERIAN DEVELOPMENT CO., THE.—Specimens of phenakite sand from Liberia.

MARSHALL, FRANCIS, ESQ.—Pyrites on quartz.

MAYO, H. J. A., ESQ.—A fossil cone from the Ferruginous Sands of Shanklin, Isle of Wight.

MERRICKS, FRANK, ESQ., C.B.E., A.R.S.M.—A gold nuggot with crystal faces, mounted as a pin.

MESOPOTAMIA, THE CIVIL COMMISSIONER IN.—A set of economic rock specimens from Mesopotamia and Southern Kurdistan. (Collected by A. H. Noble, Esq.).

NEWBOLD, MRS. ELEANOR T.—Model of a silver mine at Guanajuato, Mexico.

OSMAN, C. W., ESQ.—Crystals of inyoite from New Brunswick. Granite specimens from boring at 'Ontie Down,' Chagford. Model of twin crystal of pyrites.

OWENS, DR. J. S., F.G.S.—A fine example of artificial percussion cones in flint.

PAIN, MESSRS. A. C. D., AND R. S.—Three quartz pseudomorphs after octahedral scheelite crystals, from South Zeal, Sticklepath, Okehampton, Devonshire.

PENTLAND, THE RIGHT HON. LORD.—A walking stick of black limestone, silver mounted, with inscription 'Presented to H.E. Lord Pentland by D. Kristna Rao.'

PERKIN, DR. F. MOLLWO, C.B.E., PH.D., F.I.C.—Specimens of calcite from Nottingham.

PICKERING, CAPT.—Specimens of 'boxstone' from Wiltshire.

PRINGLE, J., ESQ., *see* KITCHIN, DR. F. L.

RAISIN, MISS C. A., D.SC., F.L.S., F.G.S.—A fine collection of about 4,000 fossils, chiefly Jurassic mollusca, formerly in the possession of the late W. H. Hudleston, F.R.S.

REINHOLD, DR. TH.—Two specimens of limestone used for lime at Maastrict and Kinrade, Holland.

RENWICK, R., ESQ.—Specimen of Stammarhan roofing stone; paving stone with ripple marks; paving stone with circular casts.

RODDA, MRS. (per W. WHITAKER, ESQ.)—Felspar twin.

SANDERS, A. B., ESQ.—Specimen of manganese ore from Brazil.

SCHAVERIEN, —., ESQ.—Three specimens of black spinel: (*a*) raw material, (*b*) cut but unpolished, (*c*) polished.

SMITH, BERNARD, ESQ., M.A.—Specimens of blende and calcite from Shropshire.

SOAMES, E. R., ESQ.—Specimens of *Stigmaria ficoides* from the Ganister of Wolsingham.

SOUTH DURHAM, STEEL AND IRON CO., LTD.—Specimens of slag, etc.

STAMP, L. DUDLEY, ESQ., M.SC.—Three specimens of associated lead and zinc ores from Lontzen Mine, Belgian Prussia.

STRAHAN, SIR AUBREY, K.B.E., F.R.S., etc.—Calamine from Holywell, and hæmatite from the Coal Measures near Frizington.

TEMPEST, P. C., ESQ., C.B.E., M.INST.C.E.—A series of photographs of the landslip in Folkestone Warren, with descriptive map.

WARREN, A., ESQ.—Specimen of picrite from Knowle Hill, Newton Abbot, Devon.

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WARREN, S. HAZZLEDINE, ESQ., F.G.S.—A series of specimens, mostly fossils, from certain wells in or near London. A large rough-worked block from the implement-bearing scree, Graig Lwyd, near Penmaenmawr; also a more finished but imperfect implement. Also two Roman blocks of calcareous tufa from East Wear Bay.

WHITAKER, W., ESQ., B.A., F.R.S.—A necklace of clear facetted amber beads.

WAY, REV. DR. J. P.—A specimen of pseudomorphous quartz from South Zeal Mine, Cornwall.

WHITE, FRANKLIN, ESQ., M.INST.M.M.—Mineral specimens from Broken Hill, Rhodesia.

WILSON, M. E., ESQ.—A series of samples representing the products of the Canadian China Clay Company, Amhurst Township, Ottawa, Canada.

WRIGHT, C. S., ESQ.—A twinned crystal of albite.

VIII.—MAPS AND MEMOIRS, ETC., PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

ENGLAND AND WALES.

I.—MAPS.

SIX-INCH REFERENCE MAPS.

The following 24 standard copies of Six-inch quarter-sheets have been made from the field copies, and are available for reference :—

Hertfordshire, 19 S.E.; 20 S.W., S.E.; 27 N.E., S.E.; 28 N.W., N.E., S.W., S.E.; 34 N.E., S.E.; 35 N.W., N.E., S.W., S.E.; 39 N.E., S.E.; 40 N.W., S.W.
Kent, 8 S.W.
London, 8 S.W., S.E.
Middlesex, 1 N.E., S.E.

II.—MEMOIRS.

PUBLISHED MEMOIRS.

Special Reports on the Mineral Resources of Great Britain :—

Vol. VI.—Refractory Materials: Ganister and Silica-Rock—Sand for Open-Hearth Steel Furnaces — Dolomite. Resources and Geology. 2nd Edition. 241 pp.; 3 plates; 8 text-figures. 1920. Price 7*s.* 6*d.* net.

Vol. VII.—Mineral Oil, Kimmeridge Oil-Shale, Lignites, Jets, Cannel Coals, Natural Gas. England and Wales. 2nd Edition. By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S., with contributions by W. Gibson, D.Sc., H. Dewey, B. Smith, M.A., C. E. N. Bromehead, B.A., J. Pringle. 125 pp.; 1 plate; 7 text-figures. 1920. Price 5*s.* net.

Vol. XII.—Iron Ores (*contd.*): Bedded Ores of the Lias, Oolites and Later Formations in England. By G. W. Lamplugh, F.R.S., C. B. Wedd, B.A., and J. Pringle. 240 pp.; 8 plates; 12 text-figures. 1920. Price 12*s.* 6*d.* net.

Vol. XIII.—Iron Ores (*contd.*): Pre-Carboniferous and Carboniferous Bedded Ores of England and Wales. By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S., W. Gibson, D.Sc., T. C. Cantrill, B.Sc., R. L. Sherlock, D.Sc., and Henry Dewey. 123 pp.; 3 plates, 10 text-figures. 1920. Price 7*s.* 6*d.* net.

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Vol. XIV.—Refractory Materials: Fireclays. Resources and Geology. 243 pp.; 4 plates, 13 text-figures. 1920. Price 8*s.* net.

Vol. XV.—Arsenic and Antimony Ores. By Henry Dewey, with contributions by J. S. Flett, O.B.E., LL.D., D.Sc., F.R.S., and G. V. Wilson, B.Sc. 59 pp.; 1 plate, 2 text-figures. 1920. Price 3*s.* net.

Vol. XVI.—Refractory Materials: Ganister and Silica-Rock—Sand for Open-Hearth Steel Furnaces—Dolomite. Petrography and Chemistry. By Herbert H. Thomas, M.A., Sc.D., A. F. Hallimond, M.A., and Ernest G. Radley. 115 pp; 7 plates, 6 text-figures. 1920. Price 5*s.* net.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1919. 70 pp.; 3 text-figures. 1920. Price 2*s.* 6*d.* net.

The Geology of Anglesey. By Edward Greenly. 980 pp., 60 plates; 17 folding-plates, 246 text-figures. 1919. In two volumes. Price 3*l.* 3*s.* net.

SCOTLAND.

I.—Maps.

Six-inch Reference Maps.

The following copies of 6-inch maps have been completed and deposited in the office for reference:—

Aberdeen, 34 N.W., N.E., S.W., S.E.; 35 N.W., N.E., S.W., S.E.; 43 N.W., N.E.; 44 N.W., N.E.
Renfrew, 15 N.E.
} Solid and Drift of each.

The revision work of the Silurian areas of the Southern Uplands of Scotland has been added to the following 6-inch clean copies (Old Series Maps) and these are now completed and deposited in the office for reference:—

Kirkcudbright, 30 N.W., N.E., S.W., S.E.; 35 N.E., S.E.; 36 N.W., N.E., S.W., S.E.; 37 N.W., N.E., S.W., S.E.; 42 N.W., N.E., S.E.; 43 N.W., N.E., S.W., S.E.; 48 N.E.

Wigtown, 1 S.W., S.E.; 2 S.W., S.E.; 3 S.W.

II.—Memoirs.

Published Memoirs.

Summary of Progress for 1919. *See* above.

Special Reports on the Mineral Resources of Great Britain:—

Vol. XI.—Iron Ores (*cont.*): The Iron Ores of Scotland. By M. Macgregor, B.Sc., G. W. Lee, D.Sc., G. V. Wilson, B.Sc., with contributions by T. Robertson, B.Sc., and J. S. Flett, F.R.S. 240 pp; 18 text-figures. 1920. Price 10*s.* net.

The Economic Geology of the Central Coalfield of Scotland. Area IV. Paisley, Barrhead, Renfrew, and the Western Suburbs of Glasgow North and South of the Clyde. By L. W. Hinxman, B.A., F.R.S.E., E. M. Anderson, M.A., B.Sc., and R. G. Carruthers, F.G.S. 110 pp.; 8 plates, 5 text-figures. 1920. Price 6*s.* net.

The Economic Geology of the Central Coalfield of Scotland. Area VII. Including the Districts of Rutherglen, Hamilton and Wishaw. By the late C. T. Clough, M.A., LL.D., the late J. S. G. Wilson, E. M. Anderson, M.A., B.Sc., and M. Macgregor, M.A., B.Sc., with contributions by R. G. Carruthers and C. H. Dinham, B.A. 144 pp.; 6 plates, 4 text-figures. 1920. Price 7*s.* 6*d.* net.

The Mesozoic Rocks of Applecross, Raasay and North-East Skye. By G. W. Lee, D.Sc., with contributions and an Appendix by S. S. Buckman, F.G.S. 93 pp.; 10 plates, 1 text-figure. 1920. Price 6*s.* net.

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APPENDIX I.

The Banffshire Coast Section of the Highland Schists.

By H. H. Read.

It is fortunate for the study of the Highland schists of North East Scotland that, in the Banffshire Coast Section (Sheet 96) there is available what is probably the most continuous section of these rocks in the Highlands. This section (Fig. 2) is over 25 miles in length, with but a few trifling gaps, all of which can be filled by adjacent inland exposures. Except at a few localities, the cliffs are easily accessible and, together with the rocky foreshore, provide magnificent sections for study. The run of the coast line is west and east, almost at right angles to the strike of the Highland schists—a circumstance showing once more the exceptional nature of this section. Upon its interpretation must depend the interpretation of the somewhat poorly exposed Buchan, Strathbogie and Lower Banffshire districts of the North-East Highlands.

No modern work has been done on this section. Amongst the early workers are numbered Jameson,[1] Prestwich,[2] Hay Cunningham,[3] Harkness,[4] and Wallace.[5] The ground was originally mapped by Dr. John Horne, and his results were published in 1895 as the present One-inch Sheet 96 (Banff) of the Geological Survey Map of Scotland.

The lithological sequence of the Highland Schists of the Banffshire coast section from west to east is as follows :—

Keith Division	(*a*) Cullen Quartzite	a^1—Findochty Beds.
		a^2—Logie Head Beds.
	(*b*) West Sands Garnetiferous Mica-Schist.	
	(*c*) Findlater Flags.	
	(*d*) Crathie Point Calcareous Group.	
	(*e*) Garron Point Actinolitic Schists.	
	(*f*) Sandend (Black Schist-Limestone) Group.	
	(*g*) Durn Hill Quartzite.	
	(*h*) Portsoy Group.	
	(*j*) Cowhythe Gneiss.	
Banff Division	(*k*) Boyne Limestone.	
	(*l*) Whitehills Group.	
	(*m*) Boyndie Bay Group.	
	(*n*) Macduff Group.	

[1] Robert Jameson, 'Mineralogy of the Scottish Isles,' vol. ii, 1800, pp. 267–279.

[2] J. Prestwich, 'On the Structure of the neighbourhood of Gamrie, Banffshire,' *Trans. Geol. Soc.*, vol. v, 1840, p. 141.

[3] J. H. Cunningham, 'Geognostical Account of Banffshire,' *Trans. High. Agric. Soc., Scot.*, vol. xiv, 1843, pp. 447–502.

[4] R. Harkness, 'On the Metamorphic Rocks of the Banffshire Coast,' *Quart. Journ. Geol. Soc.*, vol. xviii, 1862, pp. 331–336.

[5] T. D. Wallace, 'The Geology of Rathven and the Enzie,' *Trans. in. Geol. Soc.*, vol. iii, 1880, p. 331.

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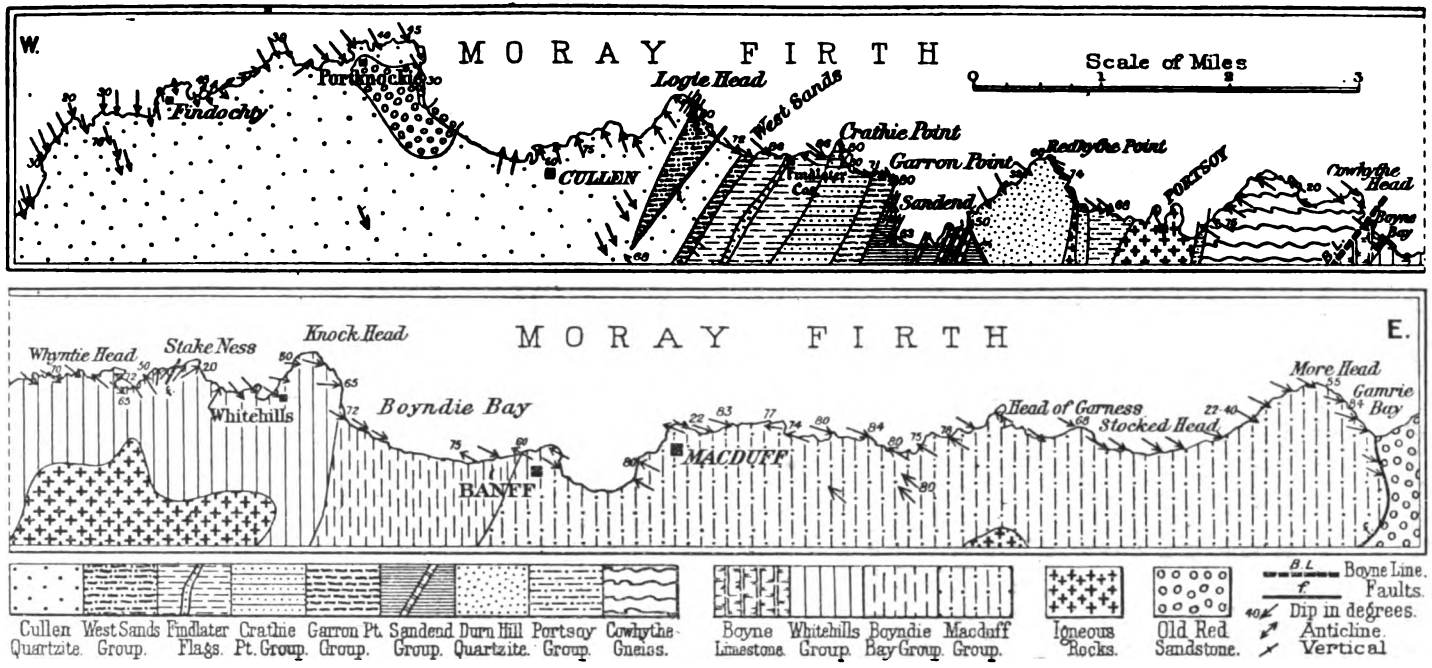

Fig. 2.—Geological Map of the Banffshire Coast.

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A short description of these groups will be given, and the reasons for the separation into two divisions developed, in what follows.

KEITH DIVISION.

(a) *Cullen Quartzite.*—This group forms the coast from Buckie eastwards to Logie Head, 1 mile east of Cullen. A detached area is found, with a breadth of 500 yds., at Sunnyside ¼ mile east of Logie Head. From Buckie eastwards to Portknockie, the coast runs parallel with the strike, and practically the same beds—the *Findochty Sub-group*, are seen all the way. The strike is about E.N.E.—W.S.W.; the prevailing dip is to the S.S.E., at rather low angles. The staple rock of the Findochty Sub-group is a very fine-grained granulitic quartzite of a white, grey or pinkish colour. The rock is massive and in thick beds; colour banding and the production of white mica in zones of intense folding have been noted. In slice, orthoclase is found to be almost always present in small amount in these rocks. Interbedded with the quartzite are many bands of dark, almost black, garnetiferous mica-schist; such bands seldom reach more than a foot or so in thickness, and are usually much less. In slice, these schists are composed of coarse, granulitic quartz, scarce orthoclase, abundant yellow-green to greenish-black biotite, scarcer muscovite and spongy porphyroblasts of pink garnet.

The remaining part of the Cullen Quartzite is formed by the *Logie Head Sub-group*. These rocks are thinly bedded and flaggy and point to the oncoming of the great flag groups to the east. The strike is about N.E.—S.W., the dip is vertical, or at high angles to the N.W. or S.E. The members of this sub-group are a rapidly alternating series of different kinds of rocks, each band averaging perhaps one or two feet in thickness. The highly crystalline granulitic quartzite of the Findochty Sub-group is still common, but here forms thinner bands. With these are associated dark, pinkish micaceous quartzites, mealy-weathering quartz-schists, buff quartzites speckled with small garnets, banded grey quartzites with thin micaceous layers, very finely banded grey and white flaggy beds with much silvery mica on the flag surfaces, very garnetiferous dark mica-schists, and thin bands of epidote-hornblende-granulite.

At the east head of Logie Head, a good transition into the next group—the West Sands garnetiferous mica-schists—is to be seen, the change taking place by the interstratification of granulitic quartzites and dark garnetiferous mica-schists, typical Cullen Quartzite rocks gradually giving place to typical West Sands schists.

Eastwards of Logie Head, the West Sands Group makes the coast for 500 yds., and then is faulted out by a fault well seen between tide marks. This fault brings on the Cullen Quartzite again for about 500 yds. until these rocks pass, by a similar

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transition phase, eastwards into the main outcrop of the West Sands Group at West Sands.

(b) *West Sands Garnetiferous Mica-Schist.*—At West Sands this group has an outcrop 120 yds. wide, with a high dip to the S.E. The group also forms the shore section for 500 yds. between the two outcrops of Cullen Quartzite, as already mentioned. In both places a gradual passage from Cullen Quartzite is seen; eastwards from West Sands, the West Sands Group passes gradually into the Findlater Flags. In West Sands, the staple rock of the group is a dark garnetiferous mica-schist, with quartzose bands and quartz kernels. In the centre of the outcrop there is a *calcareous* zone made up of thin, siliceous limestone bands, aggregating in all perhaps 2 or 3 ft. in thickness. In slice, the staple garnetiferous mica-schist is composed of two micas, quartz and garnet. The garnet forms porphyroblasts usually better shaped in the finer grained rocks.

(c) *The Findlater Flags.*—This group follows evenly eastwards from the West Sands Group and, by the incoming of calcareous material, it passes evenly into the Crathie Point Calcareous Group on its eastern margin. It forms the shore section for about 1,000 yds.; dips are high, usually to the S.E., but occasionally to the N.W. Throughout its outcrop, this group is composed of grey quartzose beds separated into flags by the development of mica on plane surfaces. Usually individual flags are about an inch or so in thickness. In slice, the typical flags are seen to be plane-foliated micaceous granulites composed of quartz and parallel plates of biotite and muscovite; the muscovite is occasionally set in large plates athwart the foliation. Garnet is seen in many slices. At Findlater Castle there is a narrow band of white, highly crystalline pure quartzite which, in slice, is seen to be composed of large sutured grains of quartz, with a very small quantity of white scaly mica.

(d) *The Crathie Point Calcareous Group.*—This group follows eastwards from the Findlater Flags, and forms the coast section between Crathie Point and Garron Point. Its width across the strike is about 570 yds.; dips are usually over 80°, and are predominantly towards the west. The main rock of the group is a pale, calcareous mica-schist, often weathering with a honeycombed yellow crust. In slice, this rock is a calc-biotite-schist, composed of about 75 per cent. calcite together with biotite, and quite subordinate quartz grains. With this calcareous flag type there are associated a few bands of very coarse, quartz-kernelled, kyanite-biotite-gneiss. Thin bands of garnet-staurolite-schist are also encountered. Towards its eastern margin, this group contains a few bands of actinolite-schist, which becomes the dominant rock in the succeeding Garron Point Group.

(e) *Garron Point Actinolitic Schists.*—This group follows evenly from the Crathie Point Group, and passes eastwards into the Sandend Group, in which rock-types characteristic of the Garron

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Point Group still persist. The width of the outcrop across strike is about 330 yds. The general dip is between 70° and 80°, and is either to the S.E. or N.W. The characteristic rock of this group is a dark, lustrous, poorly schistose rock in which there is a great development of blades of dark actinolite in felted masses, aggregates, or subradiate groupings.

Similar rocks occur at the eastern margin of the Crathie Point Group and throughout the Sandend Group, and show the essential unity of this part of the Keith Division. The actinolite-schists, unquestionably of sedimentary origin, represent the effect of regional metamorphism on an impure calcareous rock. In slice, they are composed of quartz, biotite and calcite as a ground-web, in which are set large porphyroblasts of pale green or almost colourless actinolite. With the actinolite-schists are associated flaggy micaceous quartzites and lustrous fine-grained dark grey schists with moiré surfaces.

(f) *The Sandend (Black Schist-Limestone) Group.*—This group is one of the most important stratigraphical divisions of the Highland Schists of this section. Its main rock types are black schist and limestone; stratigraphical groups characterised by these two rock types are known throughout the Highlands. On the coast the Sandend Group forms the shores of Sandend Bay and follows evenly from the Garron Point Group, but is faulted against the succeeding group on the east, that of the Durn Hill Quartzite. This fault runs N.W.–S.E., and a short distance inland what may be taken to be the full succession of the Sandend Group is found. The width of the fullest outcrop across strike is a little more than a mile; the dip is uniformly S.E. at angles of 66° to 80°. In the fullest succession there are seven broad belts of limestone, but whether these are distinct limestones or repetitions of one or more is not yet settled. A summary of the succession from the margin of the Garron Point Group eastwards is as follows :—(i) crushed good black schist with white limestone lenticles, 5 yds.; (ii) thick limestone, 17 yds.; (iii) calcareous flags, black schists, actinolite-schists and mica-schists, 170 yds.; (iv) limestone, 17 yds.; [gap of 365 yds.]; (v) limestone, 40 yds.; (vi) black schist, 230 yds.; (vii) limestone, 60 yds.; (viii) black schist, 22 yds.; (ix) limestone, 120 yds.; (x) black schist, 2 yds.; (xi) limestone, 90 yds., faulted against Durn Hill Quartzite. To this section may be added, from inland exposures in the Burn of Fordyce, the following items :—(xii) black schist with staurolite, 372 yds.; (xiii) limestone, 150 yds.; (xiv) black schist with staurolite, 230 yds., up to the approximate edge of the Durn Hill Quartzite.

(g) *Durn Hill Quartzite.*—This group takes its name from Durn Hill, 2 miles S.W. of Portsoy; it occurs on the coast at Redhythe Point between Sandend and Portsoy. The width of its coastal outcrop across strike is perhaps a mile; dips are steep and variable; the strike varies between N.E.–S.W. and N.–S. The group is faulted, on the coast, against the Sandend Group

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as has already been pointed out, but eastwards it passes into the Portsoy Group. Inland, this quartzite is at present considered to be conformable to its neighbours. The rocks of this group are more impure, more massive, less flaggy and less alternating than those forming the Cullen Quartzite already described. The most quartzose type is a felspathic quartzite composed of quartz, orthoclase, acid plagioclase and microcline, and micas. With this type are associated mica-quartz-gneisses, sillimanite-gneisses, flaggy micaceous quartzites and garnetiferous mica-schists, the last three rocks being of restricted occurrence.

(h) *Portsoy Group.*—This group occurs on both sides of Portsoy and follows on eastwards from the Durn Hill Quartzite. Its outcrop is about one mile across strike, but over half of this breadth is occupied by the sill-like mass of Older Igneous Rocks comprising serpentinised pyroxenite and peridotite, anorthosite, gabbro, enstatite-gabbro, epidiorite, amphibolite, gabbro-schist, hornblende-schist and hornblende-granulite, of which a summary has been given elsewhere.[1]

The sediments of the Portsoy Group are varied. A traverse eastwards from the east edge of the Durn Hill Quartzite shows the following succession. For 400 yds. the rocks are dark corrugated mica-schists, often silvery and garnetiferous: in this series are three narrow zones of graphite-schist. The dip hereabouts is E.S.E. or S.E. at 50°–70°. Eastwards of this belt and occupying the shore for over 100 yds. there is a very varied, rapidly alternating, group of banded calcareous flags and abundant tremolite-limestones, followed by chiastolite-staurolite-schist, dark calcareous flags, limestones and quartzose calcareous flags till the western edge of the igneous rocks is reached. Amphibolite and serpentine now form the shore for over 100 yds. Then, for about another 100 yds., a varied series of sugary white quartzite, dark mica-schist, white calcareous flags and white limestone is found before the western edge of the main mass of igneous rocks is reached. The igneous rocks form the coast about Portsoy Harbour, and include blocks of wollastonite-rock in them. The sediments, where next seen on the east shore of Links Bay, are crumpled and corrugated limy flags, impure limestones and dark mica-schists which soon pass eastwards into the next group, the Cowhythe Gneiss.

Superficially the Portsoy Group is like the Sandend Group, but when the two groups are mapped in detail, it is seen that there is really very little similarity between them.

(j) *Cowhythe Gneiss.*—This well-marked group forms the coast from Links Bay eastwards almost to the Boyne Burn. Across strike its width is a little over a mile. It follows evenly eastwards from the Portsoy Group, but is separated from the first member of the Banff Division, namely, the Boyne Limestone, by a line of

[1] H. H. Read, *Geol. Mag.*, 1919, p. 364; 'Summary of Progress for 1918' (*Mem. Geol. Surv.*), 1919, p. 26.

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disruption which may be called the *Boyne Line*. Throughout its extent the Cowhythe Gneiss is a dark, gnarled coarse biotite-gneiss with subordinate finer mica-schist bands; throughout kernels, stringers and bands of quartz are very common. In slice, the typical gneiss is composed of quartz, acid plagioclase, biotite and muscovite, occasionally with sillimanite, cordierite and tourmaline. At a point 300 yds. from its western edge, there is a calcareous horizon with about 10 ft. of white limestone, which may be called the Rosehall Croft Limestone. At the Boyne Line, the Boyne Limestone is composed of thin limestone and purplish phyllites. As these rocks are followed in towards the margin of a nose of good Cowhythe Gneiss, they are seen to be drawn out and finally to disappear against the gneiss. All around there is much brecciation and slickensiding of the rocks. A short account of the phenomena along the Boyne Line as it is traced inland will be given in a later page.

Banff Division.

(k) *Boyne Limestone.*—Eastwards of the Boyne Line, the Boyne Limestone is seen around Craig of Boyne and Boyne Bay. From the Boyne Line eastwards for perhaps 140 yds., the rocks are thin limestones, purple phyllites and banded mica-schists with quartz kernels. Several fault breccias are seen hereabouts. Eastwards follows the thick mass of Boyne Limestone, which has a width across strike of about 300 yds. This limestone is grey, blue or white, with thin intercalations of more impure material and with nests and kernels of quartz. It is violently folded and crumpled.

(l) *Whitehills Group.*—The Boyne Limestone passes eastward into this group by the incoming of purplish phyllites and the gradual disappearance of limy bands. The Whitehills Group forms the coast for three miles, and is linked on the west to the Boyne Limestone and on the east to the Boyndie Bay Group. It is a very flaggy group made up of rapid alternations of its several members. These are banded flaggy quartzites, compact fine-grained limestones, coarse gritty limestones, calcareous flags, purplish phyllites and pebbly grits with large pebbles of quartz and pink felspar. In addition, there are a few bands of nodular andalusite-mica-schist, which become more common towards the east till the next group is reached, in which they are the predominant rock type. On the whole, it may be stated that the pebbly limestones are confined to the western and central parts of the outcrop, the coarse pebbly grits and andalusite-schists to the eastern part. On Knock Head, there is a great development of coarse pebbly grit with pebbles, occasionally composite, but more often of either quartz or pink felspar, which may reach an inch or more in diameter. Several broad sills of amphibolite are found in this group about Whyntie Head.

(m) *Boyndie Bay Group.*—This group is seen in Boyndie Bay to the west of Banff. Throughout it there occur bands of pebbly

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quartz-felspar-grit like those already mentioned from the preceding group. The main rock is, however, a slaty rock, characterised by the gradual development of andalusite from a rudimentary to a complete form. The western edge of the group is characterised by silvery rocks studded with large crystals of andalusite; these are followed eastwards by rocks with elongated knots of andalusite, and these, still further east, by spotted slates which, in turn, give place to the unspotted slates of the next group. Whatever the cause of this development of andalusite, it is apparent that its effects increase in intensity from east to west.

(n) *Macduff Group.*—This great group occupies the remainder of the coast section here described, and is well exposed for a distance of 9 miles eastwards from Banff. The beds are thrown into a rapid series of steep-sided folds; but, even so, this group is probably of very great thickness. Strikes are between E.N.E.–W.S.W. and N.E.–S.W. The main rock of the group is a blue or green slate which has been worked for roofing slate at various points. With this occur in subordinate amount, pebbly quartz-felspar-grits, fine-grained grey and white grits, and fine blue greywackes.

There can be no doubt that the four members of the Banff Division form a natural stratigraphical sequence; they are linked together by transitions and by a thorough community of rock types.

It has now been shown that the Highland schists of the Banffshire coast section fall into two great divisions, separated by the line of disruption described as the Boyne Line. To the west of the Boyne Line there is the Keith Division, composed of rock types which are probably the continuation of Central Highland rocks. The Keith Division is thoroughly metamorphic in character; schists and gneisses represent the pelitic facies of the original sediments; chief among the metamorphic minerals are garnet, staurolite, kyanite and sillimanite. Eastwards of the Boyne Line is the Banff Division of which a few types recall some of those of the Loch Awe district of the S.W. Highlands. This division is much less highly metamorphosed; phyllites, rather than mica-schists, predominate in the more highly-metamorphosed parts; slates and clastic sediments are widespread; andalusite is the characteristic metamorphic mineral of this division.

If the ideas of metamorphic zones conditioned by depth of burial, advanced by C. Van Hise, F. Becke, U. Grubenmann and others, are to be accepted, then it follows that the Banff Division is structurally above the Keith Division. Further, the Macduff slates must be structurally the highest member of the Banff Division.

The phenomena along what may be considered the inland extension of the Boyne Line are not without interest. The thick

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Boyne Limestone (the thickest limestone of this section) can be followed southwards for less than 2 miles. Southwards, again, the Cowhythe Gneiss is adjacent to the Whitehills Group. Still further south, both the Cowhythe Gneiss and the Whitehills Group vanish, and in the ground to the S.W. of Huntly the Portsoy Group comes against the pebbly grits and andalusite-schists of the Boyndie Bay Group. It seems possible, therefore, that this line of disruption that has been found at the Boyne on the coast may be an important tectonic feature in the architecture of the Highland Schists of N.E. Scotland. The complete elucidation of the Boyne Line can only be obtained by the detailed study of the Buchan, Formartine, Alford and Strathdon districts of Aberdeenshire—a study which has not yet been attempted.

The Banffshire Coast Section in relation to the Highland schists of other parts of Scotland.—The chief point of interest following from this study of the Banffshire rocks seems to be their separation into two divisions. There appears to be little doubt that one of these—the *Keith Division*—represents the northern continuation of the Perthshire Schists described by Mr. George Barrow, Mr. Cunningham Craig and others, in the Memoirs on Sheets 55, 65 and 64. There seem to be very large questions still to be settled in the Perthshire ground and, until some agreement has been reached as to the stratigraphical sequence in this area, it is a hazardous proceeding to attempt any thorough correlation.

It has been shown that, in Banffshire, there are two quartzites, of which one, the Cullen Quartzite, contains rock types in a Moine state. The Cullen Quartzite is undoubtedly that seen at Ben Aigan on Speyside (Sheet 85), and the Ben Aigan Quartzite appears to be continued south by a belt of quartzite at the edge of the Moines to Inchrory in Sheet 75. South of this, the cordon of the Cairngorm, Lochnagar and Hill of Fare Granites sweeps right across the path of the Keith Division. Two quartzites, so far as I know, have not been recognised in Perthshire. There is every reason to believe that the second Banffshire Quartzite, that of the Durn Hill, is the Central Highland Quartzite of Perthshire. I hold, at present, that the Durn Hill Quartzite is conformable to its neighbours and is interstratified in the Keith Division. The relations of the Central Highland Quartzite in Perthshire are the subject of dispute.

Another fairly sure step may be made. The Sandend (Black Schist-Limestone) Group, occurring on the west side of the Durn Hill Quartzite, appears to be equivalent to the Blair Atholl (Black Schist-Limestone) Group occurring on the west side of the Central Highland Quartzite. Lithologically they are the same.

The Findlater Flags, Crathie Point Group and Garron Point Group resemble the Parallel Banded Series (Hones) and Tremolite-

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Limestone of Perthshire, and it is possible that this correlation will hold.

It has been shown that, in Banffshire, the rocks on the opposite sides of the Durn Hill Quartzite are, while somewhat similar, two distinct rock groups, those of Sandend and Portsoy. From what can be made out of the complicated and, in part, controversial description of the Perthshire ground, it appears that this independence of the two 'dark schist and limestone' groups on opposite sides of the Central Highland Quartzite has not always been recognised. In agreement, I believe, with Mr. George Barrow, I am inclined to correlate, after a short visit to the Perthshire ground, the Portsoy Group with the zone of thin limestone and dark schist seen on the south-east side of the Central Highland Quartzite on Farragon Hill and Beinn Eagach, and beside the Tummel opposite Faskally House. In the published map of this ground (Sheet 55), this Beinn Eagach group is shown as running into the Blair Atholl group on Meall Uaine, north of Pitlochry. This, from my Banffshire experience, I consider to be extremely unlikely.

To the south-east of the Beinn Eagach Group of Perthshire. there occur the Ben Lawers Schists (= Calc-sericite of Central Perthshire = Caenlochan Schists of Forfarshire, *fide* Mr. G. Barrow). These are possibly represented in Banffshire by the Cowhythe Gneiss.

No representative of the Schichallion Boulder Bed has yet been found in Lower Banffshire. It is known in Upper Banffshire at Meikle Fergie Burn, opposite Gaulrig, south of Tomintoul.

The following table of quite tentative correlations may be constructed :—

Banffshire.	Perthshire.
—	Loch Tay Limestone
—	Garnetiferous Mica-Schist
Cowhythe Gneiss	Ben Lawers Schists
Portsoy Group	Beinn Eagach Group
Durn Hill Quartzite	Central Highland Quartzite
Sandend Group	Blair Atholl Group
Garron Point Group Crathie Point Group	Tremolite-Limestone
Findlater Flags	Parallel Banded Rocks or Hones
West Sands Group	—
Cullen Quartzite	—

The *Banff Division*, with its great development of slates, pebbly grits and gritty limestones, appears to be absent in Perthshire; this division is probably confined to Lower Banffshire, Strathbogie, Cabrach, the Howe of Alford, and Buchan. A few of its rock types, notably the pebbly quartz-felspar-grits and the gritty limestones, are lithologically similar to types occurring in the Loch Awe region of the South-west Highlands. Further, the state of metamorphism is low in both areas. No

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definite correlation between the Banff Division and the Loch Awe Group is advanced here; the above suggestions, however, are to be borne in mind in any further investigation of the North-East Highlands. By the development of research in the South-West Highlands, it is possible that some light will be thrown on the problems of the Banff Division, and in particular with regard to the significance of the Boyne Line and the resemblances of this division to the Loch Awe Group.

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APPENDIX II.

Report on Sections exposed in Excavations for Sewers in the Parish of Brockenhurst, Hants.

By H. J. Osborne White, F.G.S.

1. Introduction.

The construction of the Brockenhurst Sewer-System was undertaken for the Lymington Rural District Council by Messrs. Grounds and Newton, Contractors, of Richmond Chambers, Bournemouth, according to plans prepared by Messrs. Shanton and Easdale, Engineers, of No. 28, Victoria Street, Westminster.

Begun at the lower, or Disposal-Sump, end in 1914, and discontinued during the late war, the work was resumed in the autumn of 1919, and completed, as far as excavation was concerned, by the end of December, 1920. (The full drainage-scheme includes connections with Setley, Brockenhurst Weirs, and other outlying or detached settlements, but the construction of these branches has not yet been sanctioned.)

At the request of the Director of the Geological Survey (Sir Aubrey Strahan), the author of this Report made a preliminary inspection of the ground within the area of the Sewer System on the 9th–10th July 1920, and subsequently revisited Brockenhurst on eleven occasions, between the latter date and the 1st January 1921, with the object of compiling a record, and collecting specimens, of the strata exposed in the sewer-trenches opened under the then-existing contracts with the District Council. Opportunity was taken to inspect a number of pits in the Headon Beds, near Brockenhurst, all of which were found to be in worse condition than they had been six or seven years before; and a visit was paid to parts of the Barton coast-section having a direct bearing on the stratigraphy of the Sewer area.

The writer is under an obligation to Mr. W. Faber Elliot, the Resident Engineer, for ready assistance in the examination of the Sewer works and plans, as well as for periodical communications relating to the progress of the trenching and the nature of the ground in course of excavation.

2. Geological and other Formations Exposed.

Barton Sand.—To judge by their lie and character, the oldest strata trenched belong to the uppermost 20 ft. of the Becton Bunny Beds, or middle stage of the Barton Sand, as developed in the cliffs of Christchurch Bay. They consist of evenly-bedded, fine-grained, ferrous, micaceous, muddy sands; of blue-grey tint in the deeper sections and in those below local stream-level;

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dark-yellow, orange, or brownish-red where weathered. Their junction with overlying permeable beds, whether of Barton or later age, is commonly marked by a band of orange coloration, which is fairly constant in width, as if pertaining to a definite stratum, where the cover is part of the Barton Series.

The succeeding Long Mead End Sands (about 15 ft. thick) also are fine-grained and micaceous, but contain much less argillaceous and ferruginous matter, and are normally loose and light-tinted; pale greys and yellows predominating. Near their upper limit, however, they become rather loamy and greenish-grey, owing to the introduction of green mud like that prevailing in the Lower Headon Beds above, and include thin seams of a more positively argillaceous nature. At the Sewage Disposal Works, by Haze Farm, a light-green loamy sand, inferred to lie immediately below the Headon Beds, contains marcasite-concretions; some of irregularly lenticular shape, following the lamination of the sand; others sub-cylindrical, and disposed at various angles thereto. The scanty and ill-preserved organic remains observed in the Barton Sand of the Sewer area occurred as casts (wood, *Cyrena sp.*, *Psammotea* ?) in the lenticular concretions.

Lower Headon Beds.—The lateral variation to which the members of this freshwater series are subject was apparent in the Brockenhurst trenches.

The well-marked bottom-bed, which rests evenly on the Barton Sand, normally consists of a few inches of black, dark-grey, or soot-coloured carbonaceous silty clay to loam; partly laminate or shaly; partly (where the silt element predominates) of confused, flocculate structure. When weathered, it assumes the colour and appearance of moulded chocolate, and, in the majority of the trench-exposures, this facies only was presented. In at least two sections of the Headon-Barton contact, in the southern part of the Sewer area, the bed in question was missing.

In the neighbourhood of the Railway Station, the bottom-bed is succeeded by a white to pale greyish and greenish clayey silt, mottled rusty-brown, and resembling marl, but free from calcium carbonate. Similar deposits occur at the same horizon at and about the Disposal Works, half a mile to the north-east, and at Lymington, 4 miles to the south. In the southern part of the Sewer area, however, a bright-green clay with red mottling takes the place of the pale silt, which is either absent from the lower portion of the Headon succession, or—as in one observed instance—is developed at a slightly higher horizon.

Next follows light-green to greyish-green tough clay; pure, or with silty inclusions, in the lower part, and becoming arenaceous upward through the introduction of fine white quartz-sand, which occurs chiefly in little nests and thin partings. The succeeding beds of this Series, as far as seen, are light-greenish and greyish distinctly-sandy clays and clayey-sands.

No fossils could be found, either in the trenches or on the rain-washed heaps of excavated material. Save for a little

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granular race, the visible parts of the beds had been decalcified. The maximum thickness of Headon Beds exposed was about 20 ft. It was hoped that the interesting basal ('Brockenhurst') beds of the Middle Headon, which approach to within that number of feet of the Barton Sand under Ladycross Lodge, 2 miles eastward, would be encountered in the trenches near the Railway, but nothing resembling them, or suggesting deposition under marine conditions, was forthcoming.

Valley Gravel.—The bulk of this is typical river-gravel, of fine to medium texture, sandy, clearly stratified and current-bedded. Approximately 99 per cent. of the stones are sub-angular flints; the residue is made up of flint pebbles, sub-angular Selbornian cherty sandstone, pebbles of vein-quartz, &c., all most probably derived from the Plateau Gravel of the basin of Lymington River. The sand mingled with the stones, and occurring separately in seams and lenticular banks intercalated in the gravel, is mostly of light tints, and resembles that of the highest beds of the Barton Sand. In places, beds of reconstructed dark bluish-grey (Becton Bunny) sand were met with, one of which (at Waters Green) contains remains of plants. Masses of green clay and pale silt detached from the Headon Beds are not uncommon near the boundary of that formation. Cementation of the gravel, by iron peroxide and calcareous tufa, occurs sporadically and on a small scale. The greater part of the Valley Gravel within the Sewer area is disposed in gently-inclined sheets, rising from beneath the Recent Alluvium to a height of about 20 ft. above the neighbouring streams.

Trail.—In many places the Tertiary formations and the Valley Gravel are covered by from 1 to 5 ft. of stony or gravelly loam and sandy clay, largely composed, and containing incompletely assimilated bodies, of Headon clay and sand, Barton sand, and Plateau or Valley gravel; and commonly possessing a rude flow-structure, which was well displayed in the wet, clean-cut sides of the sewer-trenches. The bottom of the deposit is markedly uneven, especially on sand and gravel, into which it descends in vertical and oblique pockets. While this pocketing —and the contortion-phenomena often associated with it—may be due in a great measure to repeated intrusion, expansion and decay of tree-roots under present-day conditions, the trail itself is most probably the outcome of exceptionally active solifluction, under bygone conditions inimical to forest vegetation.

By the progressive blending of its varied constituents, the trail passes into impure brickearth. About Brockenhurst the trail is of no little importance agriculturally, inasmuch as it masks a good deal of stiff Headon clay, and affords a retentive soil for grass and arable-land over tracts of normally barren sand and gravel.

Alluvium.—This comprises peat, sandy flood-loam (brown and of open texture near the surface; greyish and more compact below), and parts of the low-level Valley Gravel rearranged by

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the streams in Recent times. Thin peat and peaty earth or sand occupying slight hollows in the flood-loam and Valley Gravel were intersected by the trenches at Culverley Green and south-west of Brockenhurst Bridge. In the first-named locality, sand and gravel, containing much peaty matter and drift-wood were met with a few feet beneath the bed of the brook.

Made Ground.—Except in the railway-embankments and causeways, and above culverts and water-mains, the made ground cut by the sewer-trenches was of moderate or trifling thickness, and generally consisted of road-metalling. The writer neither saw, nor could hear of the discovery of, any objects of archaeological interest. The early settlement of Brockenhurst presumably lay on the spur of comparatively high ground supporting the Parish Church, outside the area of the sewer-system.

3. Rectification of the Geological Survey Map.

The boundaries of the Solid formations and of the Valley Gravel about Brockenhurst are so obscured as to render their accurate mapping impossible, without the aid of the boring-tool, or of an adventitious series of cross-sections, such as those afforded by the main-drainage works.

At Balmer Lawn, the boundary of the Headon Beds lies a little to the west of the line assigned to it in the current Geological Survey Map on the 1-in. and 6-in. scales; while in the tract between the grounds of Careys (formerly 'Brockenhurst Lodge') and Brockenhurst Weirs, it lies in places nearly half a mile south-east of that line. In the latter area, a thin spread of trail is responsible for the misleading occurrence of soils and vegetation appropriate to the Headon Beds on a low-lying portion of the Barton Sand outcrop. The Headon Beds hereabouts come on in a slight rise, which begins to be noticeable some 150 to 200 yds. north-west of, and 10 to 15 ft. below, their boundary.

The Valley Gravel proves to extend farther southward of the Lymington River than has been supposed, and to occur in considerable thickness within a few yards of its southern limit near the middle of the village. Boundary features are faint or wanting, much of the ground having been smoothly graded before and during the formation of the trail.

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APPENDIX III.

On Borings for Coal near Maryport, Cumberland.

By Bernard Smith, M.A.

Two boreholes have been put down recently, by the Cumberland Coal, Power and Chemicals, Ltd., to test the Coal Measures concealed beneath the New Red Sandstone near Maryport, on the northern side of the so-called 'Boundary Fault' of the Cumberland coalfield.

Near Maryport, at least, it was expected that higher Coal Measures would have been present than in the exposed field south of the fault; in fact, the Boundary Fault had previously been driven through in the Ten Quarters Coal at Ellenborough Colliery,[1] and Whitehaven Sandstone was said to have been entered on the north side, and to prove a great downthrow in that direction, corresponding with the downthrow observed in the Triassic Rocks.

The strata penetrated by these bores, however, did not support this view, and, moreover, did not appear to correlate with anything known in this part of the county. At the invitation of the Company the cores were first examined in detail in May 1920, and permission to publish the results has been given freely by Messrs. A. E. Barton and H. E. P. Cottrell, Directors of the Company. Our thanks are also due to Major J. G. Scoular of Oughterside Colliery, under whose supervision the borings were made.

Bank End Boring (Fig. 3).

This boring is situated close to the cemetery, 1½ miles N.N.E. of Maryport, on the west side of the road to the coast. One-in. New Series Ordnance Map, Sheet 22; Old Series Geological, 101 N.W.; 6-in. Cumb. 45 N.W. Lat. 54° 43′ 55″, Long. 3° 28′ 25″. Height of surface above O.D. 27 feet.

The boring was executed by the Sullivan Machinery Co., U.S.A. Commenced November 1919 and completed May 1920. The cores were 2-in. diam. throughout. The dip in the St. Bees Sandstone is low; in the Coal Measures it varies from about 10° to 18°, and in the Carboniferous Limestone Series from 13° in shales (1,826 ft.) to as much as 30° or 35° (1,707 ft.) in laminated sandstones.

The journal of the boring is printed in slightly condensed form as it was received from the engineers, but descriptive notes, in square brackets, have been added after examination of the cores.

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[1] 'Final Report of Royal Commission on Coal Supplies,' 1905, pt. ix., p. 17.

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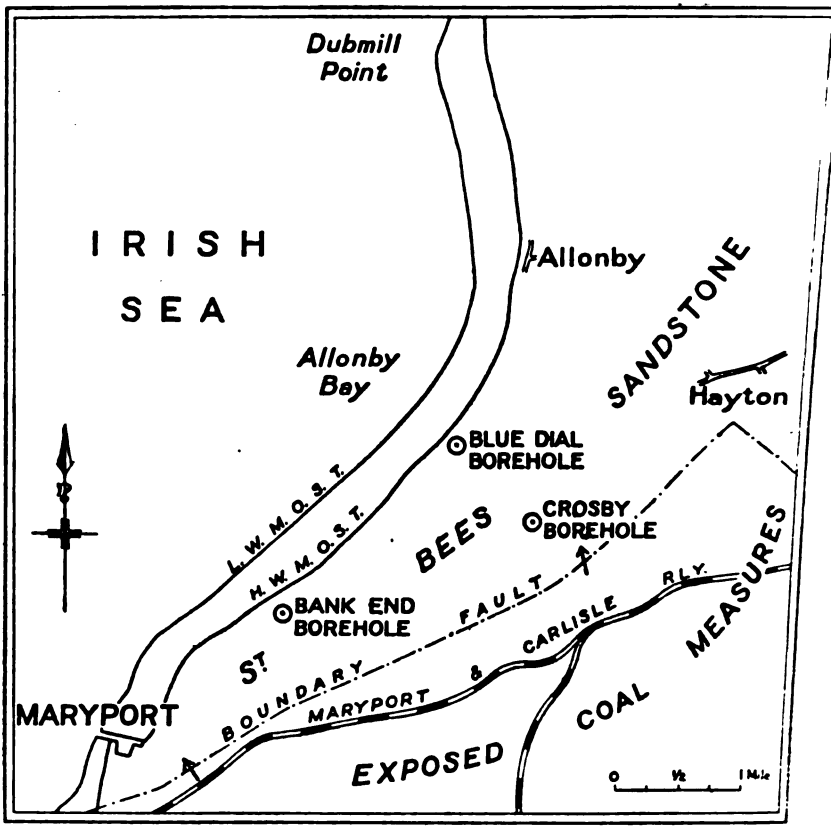

FIG. 3.—Sites of Borings near Maryport.

	Thickness. Ft.	in.	Depth. Ft.	in.
GLACIAL :—				
Gravel, clay and sandy clay	34	0	34	0
ST. BEES SANDSTONE :—				
Red sandstone, with bands of red marl and shale: thin bands of gypsum between 283 and 493 ft. [sandstones with greenish-grey bands at intervals: the chocolate-red shales are micaceous in places]	510	6	544	6
[Breccia] Base of sandstone with small marl pebbles, &c.; Red and green marls churned together; Fragments of Coal Measure shales, &c.	3	0	547	6
LOWER COAL MEASURES :—				
Rough red shale, variegated [purplish fine-grained shales and sandstones, with occasional concretions of hæmatite]	23	8	571	2
Very dark shale		4	571	6
BONE COAL [sandstone and coal mixed]	1	7	573	1
Grey sandy shale [with rootlets in upper part, on shales with ironstone balls]	10	11	584	0
Dark shale and metal [grey mud-stones with rootlets]	3	3	587	3

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	Thickness. Ft.	in.	Depth. Ft.	in.
COAL [poor and pyritous]		7	587	10
Hard grey shale	2	2	590	0
Sandy shale	6	0	596	0
Blue metal [grey and blackish mudstone with rootlets, pinnules and shells. Ironstone at 600 ft. 1 in.]	11	0	607	0
Red and dark shale, mixed	2	0	609	0
Red and grey shale [micaceous sandstone at base: spar joints]	5	0	614	0
Red sandy shale	6	0	620	0
Dark grey shale [mudstone with rootlets]	6	0	626	0
Very dark shale [with rootlets and shells]	11	5	637	5
BONE COAL with spar [and copper-pyrites]	1	1	638	6
Hard fireclay [mudstone with rootlets]	4	6	643	0
Fireclay [fine-grained, dark grey sandstone]	1	0	644	0
Grey beds and mixed sandy shale [red and black]	23	0	667	0
Light-brown sandstone [pinkish: micaceous near base]	39	0	706	0
Dark shale with variegated sandstone bands [dark and red sandy shales, both with black mica]	13	0	719	0
Dark shale [plants and shells]	2	5	721	5
BONE COAL	1	1	722	6
Fireclay [fireclay 2 ft., on sandy shale and sandstone]	7	6	730	0
Grey sandstone	3	0	733	0
Dark shale [with plants, shells and ironstone]	24	0	757	0
Black metal [smooth black shales with fossils]	1	11	758	11
COAL [poor]	2	3	761	2
Fireclay [and sandstone]	1	10	763	0
Sandy grey shale [chiefly white sandstone]	5	0	768	0
Dark shales, with ironstone [fossils]	9	3	777	3
COAL, traces of spar and sulphur [pyrites]	1	6	778	9
Fireclay	1	3	780	0
Dark grey shale [some fireclay]	18	0	798	0
Dark shale [shale and sandstone: plants]	24	4	822	4
COAL [with 3-in. roof of black shale]		11	823	3
Fireclay	2	9	826	0
Dark shales [and shaly sandstone]		10	826	10
COAL		1	826	11
Fireclay [brown and sandy]	2	1	829	0
Dark shale and grey bed [with current-bedded sandstones, and plants]	30	0	859	0
White sandstone on dark shale [plants]	10	0	869	0
Fireclay with ironstone bands near base	4	6	873	6
Grey sandstone	25	9	899	3
Dark shale [black: ironstone balls, and fish remains]	9	3	908	6
Fireclay [pulped shale on black shale]	2	0	910	6
COAL [poor]	1	9	912	3
Fireclay	2	9	915	0
Sandy shale	16	0	931	0
Fireclay [grey shale, on 18 in. fireclay]	5	0	936	0
Sandy shale and grey bed [1 ft. fireclay: plants]	15	0	951	0
Sandy and dark shales [soft black and micaceous: shells and plants]	25	10	976	10
COAL [core missing]		5	977	3
Dark shale [plants and ironstone]	6	9	984	0

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	Thickness. Ft.	in.	Depth Ft.	in.
COAL [poor, with calcite joints]		8	984	
Fireclay	1	4	986	
Dark shales [mudstone with ironstone]	5	2	991	
COAL [poor]		11	992	
Fireclay	1	11	994	
White sandstone	27	0	1,021	
Fireclay and dark shale	5	0	1,026	
CARBONIFEROUS LIMESTONE SERIES :—				
Dark shales with shells and spar bands [crinoids and marine shells]	1	0	1,027	
Sandy shales [white sandstone with dark shale and coaly layers]	4	0	1,031	
Dark shales	1	0	1,032	
Hard fireclay [shaly at top]	5	0	1,037	
Fireclay [greenish shale]	3	0	1,040	
Dark shale [shales and mudstones; ferrous carbonate and pyrites]	10	0	1,050	0
Dark shale	10	0	1,060	0
Dark brown shale [fossiliferous]	9	0	1,069	0
Grey bed, hard post and sandstone [whitish quartzose sandstone, with black mica, and 1 foot shale]	36	0	1,105	0
Dark shale with ironstone nodules and few shells	4	0	1,109	0
Hard dark shale [fossiliferous]	16	0	1,125	0
Dark firelay [smooth micaceous shale and bastard cannel]		8	1,125	8
COAL, very dirty [full of calcite]		4	1,126	0
Fireclay	1	6	1,127	6
Very coarse grey bed [sandstone and shales]	18	6	1,146	0
Dark shale with ironstone, pyrites and crinoids, on sandstone and shale : limestone at 1,171 ft.]	30	0	1,176	0
Sandstones and sandy shales [fossiliferous]	139	0	1,315	0
Red sandstone [pink, purple and white : micaceous]	13	0	1,328	0
Fireclay [dark grey, black and purple : micaceous]	2	0	1,330	0
Grey bed [20 ft.], on sandstone	48	0	1,378	0
Dark grey sandy shales [black mica and plants]	4	0	1,382	0
Grey bed, separated by sandstone, 4 ft. [plants]	23	6	1,405	6
Black shale [shells and plants]	12	0	1,417	6
Hard dark shales [dull sandy shales, calcareous in places : highly fossiliferous. *Reddish limestone* at 1,425 feet]	44	0	1,461	6
Red, on white, sandstone [white, pink and red, micaceous and with shales]	16	6	1,478	0
Black shale [mixed with sandstone : plants]	12	0	1,490	0
Dark black, sometimes sandy, shales and grey bed [pyrites nodules and traces of plants]	35	0	1,525	0
White sandstone [purplish in places : coaly layers]	13	9	1,538	9
Dark shale with 1 in. COAL		3	1,539	0
Grey bed and white sandstone, mixed	17	9	1,556	9
COAL		6	1,557	3
Brown shale		3	1,557	6
Fireclay [black, with rootlets]	3	0	1,560	6
Sandstone and grey bed	16	6	1,577	0
Dark shales, grey beds and sandy shales [plants, crinoids and shells from 1,636–1,637 ft.]	79	0	1,656	0
White sandstone	12	0	1,668	0
Dark shale and grey bed	27	6	1,695	6
Broken dark shale [1,697–1,698 ft., dark shale on black shale with *Lingula*]	3	6	1,699	0

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	Thickness. Ft.	in.	Depth. Ft.	in.
COAL—*continued.*				
Sandstones and grey beds, some red	37	0	1,736	0
Grey bed and dark shales	65	0	1,801	0
Sandstones, grey beds and shales [fossils at 1,826–7 ft.]	96	0	1,897	0
Grey and white sandstone	24	6	1,921	6
Dark shale [with sandstone: fossils at 1,954 ft. 6 in. in ferrous carbonate]	63	6	1,985	0
Grey bed, sandstone and shale with spar	14	0	1,999	0
Dark shales and sandstones, mixed	75	0	2,074	0
White sandstones and grey beds	157	0	2,231	0
COAL		4	2,231	4
Shale, sandstone and grey bed	64	8	2,296	0
COAL		4	2,296	4
Dark shale, grey beds, sandstones and shales	250	8	2,547	0
COAL		3	2,547	3
Shale and sandstone	36	3	2,583	6
COAL, small pieces	1	10	2,585	4
Sandstone, grey bed and shale	62	8	2,648	0

BLUE DIAL BORING (Fig. 3).

This boring is, in its essentials, similar to the above, but was finished at a slightly later date. It is situated close to the coast-line nearly 2 miles N.E. of the Bank End boring and about 200 yds. S.W. of Blue Dial. Six-in. Cumb. 35 S.W. Lat. 54° 45′ 9″, Long. 3° 26′ 25″.

Height of surface above O.D. 21 ft.

The dip of the lower series is in places as high as 30°.

A summary of the chief divisions is as follows:—

	Thickness. Ft.	in.	Depth. Ft.	in.
GLACIAL	46	6	46	6
ST. BEES SANDSTONE, with 3-in. breccia at base	664	6	711	0
LOWER COAL MEASURES, stained red and purple to about 880 ft., with 13 thin coals	951	0	1,662	0
CARBONIFEROUS LIMESTONE SERIES, with coal and shale parting at from 2,043 ft. 8 in. to 2,045 ft. 8 in.	673	0	2,335	0

The breccia at the base of the Trias in this boring consisted of small pellets of New Red Marl and Sandstone in sandstone, on small fragments of Coal Measure shales. There was also a thin layer of fibrous gypsum close above the breccia. The junction was difficult to detect owing to the staining of the underlying Coal Measures.

The base of the Coal Measures in each boring has been fixed at a point below which there is the first appearance of crinoidal and shell-bearing shales of marine type. Lithologically, however, apart from some thin bands of limestone, calcareous shales, or calcareous sandstone, the lower series bears a resemblance to the Coal Measures. Bands and balls of ferrous carbonate and pyrites occur in both, and certain shales and sandstones contain black mica. Plant remains also occur in both. There is no sign of unconformity at the junction in either section.

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The 'grey-beds' are usually alternations or admixtures of sandstone and shale.

The Coal Measures contain no coals that can be recognised in neighbouring collieries and none appears to be of value. The coals in the underlying beds are apparently placed for the first time at their proper horizon, although they may have been bored through or may crop out in the district.

The fossils given below have been examined and named by Mr. J. Pringle and Dr. Robert Kidston, F.R.S.

LIST OF FOSSILS FROM BANK END BOREHOLE, MARYPORT, CUMBERLAND (B.S. 1439–1803).

	Depth in Feet.
Mariopteris muricata (*Schloth.*)	802–807
Neuropteris heterophylla *Brongn.*	735–744
,, *cf.* ,,	566, 570
,, tenuifolia (*Schloth.*)	818–820
,, *cf.* ,,	802–807
,, sp.	802–807, 818–820
Sphenopteris *cf.* obtusiloba *Brongn.*	802–807
Calamites sp.	735–744
Cf. Calamites carinatus *Sternb.*	,,
Asterophyllites charaeformis (*Sternb.*)	783
,, equisetiformis (*Schloth.*)	802–807, 818–82
Calamostachys sp.	818–820
Lepidophyllum sp.	958
Stigmaria ficoides (*Sternb.*)	980
Cordaites sp.	818–820
[1]Carbonicola *cf.* aquilina (*J. de C. Sow.*)	600, 630
[1] ,, sp.	571, 600–607, 631, 744–7
[1] ,, ?	744–747, 901
Crinoidal columnals	1,048, 1,068, 1,171
Fenestellid	1,062
Lingula squamiformis *Phill.*	1,697
,, *cf.* ,,	1,173
,, sp.	1,100
,, ?	977
Orbiculoidea nitida (*Phill.*)	1,428
Productus, *cf.* longispinus *J. Sow.*	1,425
,, sp.	1,425, 1,440
,, ?	1,280, 1,412
Schellwienella sp.	1,425
Cypricardella sp.	1,280
Euphemus urei ? *Flem.*	1,045
Coelacanthus sp.	571
Rhizodopsis sauroides *Will.*	571, 904
,, ,, ?	953–955
,, ?	632
Fish remains, indet.	906

[1] Freshwater shells.

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Mr. Pringle states that 'the marine shells which characterise the rocks passed through between the depths of 1,045 ft. and 1,697 ft., suggest comparison of the beds with the Cefn-y-Fedw Series of Denbighshire.' The latter has been shown in recent years to belong to the Carboniferous Limestone Series. Previously it had been termed 'Millstone Grit.'

The absence in these records of the 'Millstone Grit' of the Whitehaven District, and the extraordinary difference between the Carboniferous Limestone Series in the borings, which is of northern aspect, and that developed in the above district, where by far the greater part is massive limestone, are points of great interest and of economic importance, the significance of which will be better appreciated when the systematic mapping of the area is taken in hand and the various changes followed in detail.

That these changes have taken place before the Boundary Fault is reached from the south is proved by a boring recently sunk by the same Company at Hayborough, about 1 mile east of Ellenborough, in which strata of the Upper Carboniferous Limestone types met with at Bank End and Blue Dial crop out beneath the Glacial beds. Again strata of this lithological character, containing a thin limestone with *Schellwienella*, are exposed in two dingles ½ mile S.E. of Rosegill, and about 3½ miles east of Maryport.

A further point of interest is that the borings tend to prove that there must have been a downthrow (or steep turn-over) south-eastward along, or near the line of, the Boundary Fault, before the date of the Triassic overlap and the later northward downthrow. The supposed Whitehaven Sandstone met with in the above-mentioned driving through the fault, from the Ten Quarters Coal at Ellenborough, may well have been some of the sandstones of the Lower Coal Measures or Upper Limestone Series coloured by Triassic infiltrations.

The Crosby borehole[1] (Fig. 3) appears to have proved a sequence similar to that of the two borings under consideration, but in the absence of fossil evidence it is impossible to say exactly at what depth the Carboniferous Limestone Series was first reached—probably at much shallower depth than 1,046 ft. 9 in. which marks the top of a 33 ft. 3 in. bed of limestone. It appears, therefore, that, in the absence of faults, the base of the Coal Measures of this area strikes more or less parallel to the Boundary Fault and may dip seawards at something like 1,300 ft. per mile—an average dip of from 13° to 14°, which corresponds fairly well with the actual dips observed in the cores. The generally higher dip in the lower series is suggestive of unconformity.

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[1] *Ibid.*

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APPENDIX IV.

On a Boring for Coal at Yate, Gloucestershire.

By J. Pringle.

This borehole is situated in a field on the north side of the Bristol road 400 yds. west of Yate Station,[1] at a surface level of 225 ft. above O.D. The operations, which were carried out by Messrs. Vivian's Boring and Exploration Company, Limited, under the management of Mr. Fisher Ray, were begun in August 1918, and were completed in July 1920, after a depth of 2,203 ft. had been reached. The object of the boring was to ascertain the character of the Lower Coal Series present in the eastern limb of the synclinal fold that forms the northern point of the Bristol coalfield. An almost continuous series of cores was obtained by drilling from the surface down to the bottom of the borehole; and through the kindness of Mr. R. M. Dillwyn of Bridgend, Glamorgan, permission was granted to the Geological Survey to examine the rocks thus displayed. A series of rock-samples and fossils was collected, and these are now included in the Survey Collections at Jermyn Street.

The following is an abstract section of the borehole :—

	Thickness. Ft.	in.	Depth. Ft.	in.
Soil and rubble	2	9	2	9
Coal Measures—				
Pennant Series :—				
Grey pennant sandstone with beds of grey sandy shale and a seam of fireclay. Sandstones contain many films of coal, ironstone-nodules, and a few pebbles of coal	853	5	856	2
Soft coal		2	856	4
Strong grey fireclay and grey sandy shale with ironstone	31	5	887	9
Coarse grey conglomerate with many large sub-angular pebbles of quartzite, &c.	4	9	892	6
Bluish-grey and red marls	41	3	933	9
Coarse grey conglomerate, as above	10	9	944	6
Bluish-grey and red marls	6	0	950	6
Grey shaly sandstone	5	3	955	9
Grey conglomerate with many large pebbles	28	7	984	4
Grey pennant sandstone with bands of shale and conglomerate. Joint planes lined with calcite	74	6	1,058	10
Lower Coal Series :—				
Bluish-grey and red marls	8	8	1,067	6
Grey quartzose sandstone	1	9	1,069	3
Bluish-grey sandy shale	19	9	1,089	0
Fine grey sandstone with courses of conglomerate	1	6	1,090	6
Grey and red sandy shale	5	3	1,095	9
Grey shale	35	0	1,130	9

[1] New Series 1-in. Ordnance Map, Sheet 251 (Malmesbury); 6-in. map Gloucestershire 69 S.W.; Old Series 1-in. Geological Map 35, Lat. 51° 32′ 24″, Long. 2° 26′ 12″.

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Coal—*continued.*	Thickness.		Depth.	
Lower Coal Series—continued.	Ft.	in.	Ft.	in.
Grey sandstone with bands of shale and conglomerate	6	3	1,137	0
Coal		9	1,137	9
Fireclay, sandy shale, and sandstone	20	7	1,158	4
Grey shale	17	0	1,175	4
Coal		2	1,175	6
Fireclay	11	9	1,187	3
Grey shale with a band of grey sandstone, 6 ft. thick, between 1,205 ft. and 1,211 ft. *Marine Band* at 1,227 ft.	68	3	1,255	6
Black shale	3	0	1,258	6
Coal	1	9	1,260	3
Grey fireclay and shale	12	0	1,272	3
Dark-grey and red mottled marl	5	0	1,277	3
Grey shale	18	3	1,295	6
Coal		3	1,295	9
Red and grey mottled marl	53	0	1,348	9
Grey shale	36	3	1,385	0
Coal, soft		3	1,385	3
Grey shale	107	0	1,492	3
Grey sandstone	16	5	1,508	8
Grey shale, numerous plant remains throughout	19	1	1,527	9
Coal, soft	1	6	1,529	3
Coal, soft, and black shale, mixed	1	10	1,531	1
Coal, soft	2	6	1,533	7
Dark shale		10	1,534	5
Dark shale and coal with numerous poorly preserved plants	1	0	1,535	5
Dark grey shale	29	1	1,564	6
Coal	1	0	1,565	6
Grey shale and shaly sandstone. *Marine Band* at 1,610–1,616 ft.	67	3	1,632	9
Red and bluish grey marl	19	3	1,652	0
Dark-grey shale	3	0	1,655	0
Coal		4	1,655	4
Grey shale	37	3	1,692	7
Grey sandstone	6	0	1,698	7
Grey shale	82	9	1,781	4
Grey fireclay	2	0	1,783	4
Grey sandy shale	8	3	1,791	7
Grey sandstone	1	9	1,793	4
Grey sandy shale with numerous plant remains	19	10	1,813	2
Coal	2	0	1,815	2
Dark-grey shale and fireclay	10	6	1,825	8
Grey sandstone	1	10	1,827	6
Grey shale with band of ironstone	27	7	1,855	1
Grey fireclay	1	8	1,856	9
Coal, soft		8	1,857	5
Grey shale with band of ironstone	39	2	1,896	7
Coal, soft	1	2	1,897	9
Dark shale and fireclay	33	7	1,931	4
Grey sandstone		10	1,932	2
Dark-grey shale	3	9	1,935	11
Coal, soft		9	1,936	8
Dark shale	1	6	1,938	2
Coal, soft		8	1,938	10
Dark shale	2	0	1,940	10
Coal, soft		9	1,941	7
Dark shale		9	1,942	4

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Coal—*continued.* *Lower Coal Series*—continued.	Thickness. Ft.	in.	Depth. Ft.	in.
Coal	3	2	1,945	6
Grey shale and sandstone	19	4	1,964	10
Coal	1	4	1,966	2
Grey shale, fireclay, and sandstone	49	5	2,015	7
Coal	4	0	2,019	7
Black shale		5	2,020	0
Coal	1	0	2,021	0
Dark shale	2	4	2,023	4
Fireclay	4	0	2,027	4
Grey shale	13	3	2,040	7
Coal		3	2,040	10
Fireclay, shale, and sandstone	32	0	2,072	10
Grey shale with band of ironstone	38	1	2,110	11
Coal, soft	1	2	2,112	1
Dark-grey shale with band of ironstone	91	3	2,203	4

The dip of the beds, taken at various intervals, appeared to range between 10° and 35°. The rock-sequence displayed in the cores is generally similar to that passed through at Winterbourne,[1] in the western part of the coalfield; but some minor differences were noted. The base of the Pennant Series has been drawn at the depth of 1,058 ft. 10 in., and its position in relation to the highest marine band is nearly the same as in the two corresponding levels at Winterbourne. Beds of coarse conglomerate form a characteristic feature in the lower part of the Pennant Series, although similar but thinner and less coarse pebbly bands occur also in the upper portion of the Lower Coal Series. Many of the pebbles are of large size, one, a grey quartzite from 980 ft., measuring 5 in. in length; and in appearance the conglomerates are identical with those passed through at Winterbourne. Dr. H. H. Thomas, who has examined the specimens, reports that the pebbles are for the most part fine-textured rocks, variously coloured green, grey, and pink, embedded in a matrix which is highly felspathic and quartzose, much of the quartz being opalescent. The chief rock-types are quartzites, rhyolites, and vein-quartz, and, excepting a specimen of a fine-grained brownish sandstone, possibly of Carboniferous age, the whole assemblage, which is seemingly identical with that found at Winterbourne, again suggests derivation from rocks of Pre-Cambrian formations. No pebbles of the older Palæozoic sediments were recognised. The majority of the pebbles are sub-angular, and their marked increase in size, as compared with the constituents of the Winterbourne conglomerates, suggests that the source of the material lay somewhere east or north-east of the coalfield, and may indicate the presence of a buried ridge of Pre-Cambrian rocks in that direction.

In the Lower Coal Series beds of sandstone resembling Pennant rock are present, but they are subordinate to the argillaceous sediments, which are chiefly of the mudstone type.

[1] T. C. Cantrill and B. Smith, 'On a Boring for Coal at Winterbourne, Gloucestershire,' 'Summary of Progress for 1918' (*Mem. Geol. Surv.*) 1919, pp. 53–57.

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The lower shales are remarkably slicken-sided. Most of the coals are soft and thin, and are frequently interbedded with shale. A seam of good quality, 4 ft. thick, was passed through between the depths of 2,015 ft. 7 in. and 2,019 ft. 7 in. It is separated from a lower coal, 1 ft. thick, by 5 in. of black shale. Two marine bands were detected in the measures. At 1,227 ft. fragments of *Lingula* were found in association with numerous shells of *Orbiculoidea nitida* (Phill.); and between the depths of 1,610 and 1,616 ft. the shales yielded several finely ribbed specimens of *Productus*. These marine bands appear to represent similar horizons passed through at the depths of 1,090 and 1,488–1,494 ft. in the Winterbourne boring. Some of the shales were found to be crowded with plant-remains, but considerable thicknesses yielded no fossils. The identification of the plants by Dr. R. Kidston F.R.S. is as follows :—

	Depth in Feet.
Alloiopteris (Corynepteris ?) coralloides (*Gutbier*)	1,909
Linopteris *cf.* obliqua *Bunbury*	1,171
Lonchopteris bricei *Brongn.*	1,974
Mariopteris sp.	1,171
Neuropteris tenuifolia (*Schloth.*)	1,525, 1,711
,, sp.	1,525, 1,697, 1,711, 1,719
Pecopteris (Dactylotheca ?) sp.	1,697
,, sp.	1,562
Sphenopteris *cf.* artemisiæfolioides *Crepin*	1,525
,, obtusiloba *Brongn.*	1,711
,, sp.	1804–1810
Calamites cisti *Brongn.*	,,
,, sp.	,,
Annularia microphylla *Sauveur*	1909
Asterophyllites equisetiformis *Schloth.*	1,525
Palæostachya sp.	1,973
Lepidophyllum lanceolatum *L. & H.*	1,711
Sigillaria mammillaris *Brongn.*	1,510
Cordaites principalis (*Germar*)	1,525
,, sp.	1,711, 1,804, 1810

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APPENDIX V.

TOTAL QUANTITY OF TIN, COPPER, AND OTHER MINERALS PRODUCED IN DEVONSHIRE, PARTICULARLY WITH REGARD TO THE AMOUNTS RAISED FROM EACH PARISH.[1]

By Donald A. MacAlister, A.R.S.M.

Many of the mines of Devon, like a still greater number in Cornwall, have long since been abandoned, and the topographical positions of such as are mentioned in records have only been determined after laborious examination of hundreds of old mine-plans preserved in local estate offices and institutions; in the Office of Woods and Forests, the Home Office, the Duchy Office and the Geological Survey, as well as a number in private ownership. It was only by this means that the recorded output of minerals could be classified according to parishes.

The tabulation of the production according to parishes presents a shorter and more rational account of the economic value of a mineral tract of country than could be obtained by a detailed list of outputs from the individual mines.

The totals from each parish during the periods are computed from the separate returns of the mines in them, as derived from the various sources mentioned on p. 274 of the *Geology of Falmouth and Truro*. As it was not until 1882 that continuous and reliable returns were published, it is likely that the details of the Tables fall short of the true amounts raised in the periods covered, and the reservations stated in the *Summary of Progress* referred to, as well as those in the memoir last cited (p. 274) must be borne in mind when considering the value of any mineral area. It will be recognised that although the records of early production are fragmentary there is enough evidence of different kinds to show that several of the ores have been worked from time to time for centuries past, and that it is impossible to embody such information in the Tables.

Mr. Lewis[2] states that the statistics of the production of tin from Cornwall and Devon in the late 12th century are not plentiful and relate mostly to Devonshire. From his perusal of the pipe-rolls Mr. Lewis was able to draw up tables of annual returns in which, however, there are many lacunæ amounting in the aggregate to several hundred years. The value of any attempt to estimate the quantities produced in the missing

[1] For the output from the parishes of Cornwall *see* 'Summary of Progress of the Geological Survey of Great Britain for 1906' (*Mem. Geol. Surv.*), Appendix II, 1907, p. 132.

[2] '*The Stannaries*', 1908.

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years would, at best, be doubtful, as even if the existing records were reliable, we should still have to assess the effect on production due to wars and social conditions, in addition to the usual uncertain elements in mining and trade. It may be noted, however, that from the 13th century to the middle of the 18th century many tens of thousands of tons of metallic tin were produced from the West Country.

With regard to copper it is quite certain that the ore was raised concurrently with tin-ore from the earliest historical times; but Lysons states[1] that in 1811 only seven mines in Devon were yielding copper, and that in that year the production was as follows:—Wheal Friendship, 110 tons; Wheal Crebor, 1,308 tons; Crowndale, 863 tons; East Crowndale, 913 tons; Wheal Hockworthy, 10 tons.

The early official statistics are far from satisfactory, and although care has been taken in the Tables which follow to present a true account in accordance with available data, the amounts here given should be regarded merely as useful guides to the relative importance of the mineral areas.

We may briefly recall the fact that the available records contain many lacunæ and probably mistakes,[2] so that although we know the sources we do not know the precise extent of the errors likely to be present. The observations contained in Appendix II. of the *Summary of Progress* already referred to apply with equal force to the mineral output of Devon and need not be repeated.

The periods covered by the Tables are necessarily restricted to the 19th and 20th century, as earlier records are scarce and discontinuous.

The principal production of lead ore was in the forties and fifties of the 19th century, though it continued to be raised until the eighties; the silver was obtained mainly from the lead. We recall, however, the historical fact that the silver-lead mines of Devonshire were worked at least as far back as the 13th century.[3] Manganese was actively mined in the seventies, but we note that considerable quantities of this ore, as well as iron ore, were raised in the 18th as well as the early part of the 19th century.[4] Zinc ore was raised mainly in the fifties and sixties. The output of tin ore, as expressed in the Tables, is limited to that since 1852; of copper ore since 1821; of lead ore since 1845; of silver since 1852, and of miscellaneous minerals since 1853.

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[1] *Mag. Britt.*, Devon, p. cclxxxiii.

[2] Such as those due to confusion between the natural and dressed ores and the metal, as well as to false returns.

[3] *See* 'Geology of Cornwall, Devon and West Somerset' (*Mem. Geol. Surv.*), pp. 611, 612.

[4] *Op. cit.*, pp. 610, 617.

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TABLE I.—*Output of Tin and Copper from the Mines of Devonshire, grouped according to the Parishes in which they occur. The Tin Ore produced from* 1852 *to* 1913; *and the Copper Ore from* 1821 *to* 1913.

Parish.	Black Tin.	Copper Ore.	Copper.[1]	Parish.	Black Tin.	Copper Ore.	Copper.
	Tons	Tons.	Tons.		Tons	Tons.	Tons.
Ashburton -	804	421	17	Molland - -	—	1,180	75
Beer Ferris -	10	205	13	North Bovey -	1,314	—	—
Belstone -	1	4,036[2]	375	North Molton	—	4,515	638
Bovey Tracey	—	2,300	86	Okehampton -	—	2,656	186
Buckfastleigh -	—	29,680	1,965	Peter Tavy, *see* Mary Tavy.	—	—	—
Buckland Monachorum	12	24,250	1,400	Plympton St. Mary - -	1,300	240	12
Chagford - -	60	—	—	South Tawton	—	6,285	344
Dartington -	56	—	—	Sydenham Damerel -	—	80	5
Holne - -	6	—	—	Tavistock -	300	933,210	59,682[3]
Ilsington -	91	—	—	Walkhampton	220	280	21
Lamerton -	61	22,600	1,285	Whitchurch -	515	20,630	1,538
Lydford - -	295	—	—	Miscellaneous -	10	1,150	80
Manaton -	203	—	—				
Mary Tavy -	408	43,250	4,015				
Meavy - -	400	—	—				

[1] Obtained from the copper ore mentioned in the previous column.
[2] Over 1,000 tons contained about 9 per cent. copper.
[3] In addition, about 90 tons of 'precipitated copper' yielding 70 per cent. of the metal.

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TABLE II.—*Output of Minerals, other than Tin and Copper, from the Mines of Devonshire, grouped according to the Parishes in which they occur. The Lead Ore raised since* 1845; *the Silver since* 1852; *and the Miscellaneous Minerals since* 1853; *to* 1913.

Parish.	Lead Ore.	Lead.[1]	Silver.[2]	Pyrites (Iron and Arsenical).	Arsenic[3] Soot (and White).	Iron Oxides.	Miscellaneous Minerals.
Ashburton - -	Tons. —	Tons. —	Ozs. —	Tons. 720	Tons. 903	Tons. 22,060	The pyrites mostly arsenical. The iron oxides are 'Brown Hæmatite,' ochre and umber. Of this, 12,820 tons of ochre and umber were returned from 'Roborough' and 'Devon and Cornwall' Mines, and some from 'S. Devon Mine,' which also returned 690 tons 'spathic iron.'
Beer Ferris - -	25,670	16,324	534,010	20	—	—	The pyrites non-arsenical. Also 3,240 tons of fluor-spar.
Belstone - - -	—	—	—	102	21	—	Of the pyrites, 72 tons were arsenical.
Bovey Tracey - -	—	—	—	—	—	2,878	Of which 1,060 tons 'micaceous' iron ore, 123 tons ochre and 667 tons 'Brown Hæmatite.'
Bratton Fleming -	—	—	—	—	—	20	Red Hæmatite. Also 10 tons of manganese ore, part of which came from Sherwell Parish, *q.v.*
Brentor - - -	—	—	—	—	—	155	Ochre. Also 3,610 tons of manganese ore.
Bridford - - -	—	—	—	—	—	—	21,250 (?) tons of barytes.
Brixham - - -	—	—	—	—	—	196,311	Mainly 'Brown Hæmatite,' containing up to 50 per cent. iron. Some micaceous and some sold as ochre and 'Wolston's iron paint.'

[1] From the lead ore. [2] From the lead. [3] In addition to the arsenical pyrites.

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TABLE II.—*continued.*

Parish.	Lead Ore.	Lead.	Silver.	Pyrites (Iron and Arsenical).	Arsenic Soot (and White).	Iron Oxides.	Miscellaneous Minerals.
	Tons.	Tons.	Ozs.	Tons.	Tons.	Tons.	
Buckfastleigh	—	—	—	350	—	—	Of which a proportion was arsenical.
Buckland Monachorum	—	—	—	7,575	1,715	—	Pyrites mainly arsenical.
Budeaux	62	36	1,436	—	—	—	
Challacombe	—	—	—	—	—	50	'Brown Hæmatite.'
Chevelstone	—	—	—	—	—	300	'Brown Hæmatite.'
Christow	26,550	17,506	367,230	—	—	689	Of the iron oxides, 48 tons were ochre and umber; 240 tons 'Brown Hæmatite,' and 182 tons 'spathic iron ore' (*see* Lustleigh). In addition, 180 tons of fluor-spar and 1,635 tons of zinc-ore.
Combe Martin	860	545	812	—	—	1,340	Of the iron ore, 450 tons were 'Brown Hæmatite,' and 890 tons 'umber.' In addition, 1,590 tons of 'spathic iron ore.'
Coryton	—	—	—	—	—	—	*See* Milton Abbot.
Georgeham	—	—	—	—	—	780	'Brown Hæmatite.'
Harford	—	—	—	—	—	900	'Brown Hæmatite.'
Hennock	800	550	1,190	—	—	1,935	The oxide of iron was 'micaceous iron ore.' In addition, 1,200 tons of manganese ore.
Ilsington	93	60	80	—	—	46,512	Of the iron oxides, 21,928 were magnetite, 16,209 'Brown Hæmatite,' 5,717 mixed 'Brown Hæmatite' and micaceous iron ore ('shining ore'), containing up to 57·5 per cent. of iron, 708 tons of ochre, 340 tons of umber, 220 tons of so-called 'Wolston's iron paint.' In addition, 1,474 tons of zinc-ore.

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Kingsbridge	—	—	—	—	—	54	'Brown Hæmatite.'
Lamerton	62	39	2,915	1,410	1,011	—	Of the pyrites, 350 tons were arsenical. In addition, 602 tons of zinc ore and 77 tons of manganese ore.
Lew Trenchard	—	—	—	—	—	—	156 tons of Manganese ore. *See also* Marystow and Milton Abbot.
Lustleigh	—	—	—	—	—	1,580	Part of this from Bovey Tracey and Shuttamoor in Christow; 342 tons were 'Brown Hæmatite,' and the rest 'shining ore.'
Lydford	12	8	—	—	—	—	
Marlborough	—	—	—	—	—	100	
Marystow	—	—	—	—	—	—	1,820 tons of manganese ore, but this includes some from Milton Abbot, Lew Trenchard, Cardwell and St. Stephen.
Mary Tavy	2,000	1,176	9,150	17,875	7,685	—	Of the pyrites, 10,508 were arsenical. In addition, 160 tons of zinc ore. 'Scheelite,' and 1 ton of Wolfram from Wheal Friendship.
Milton Abbot	—	—	—	—	—	—	49,890 tons of manganese ore, but part of this came from Lifton, Sydenham Damerel, Lew Trenchard and Coryton. *See also* Marystow.
Molland	—	—	—	—	—	28,560	'Brown Hæmatite.'
North Bovey	—	—	—	—	—	25	Specular iron or 'shining ore.'
North Molton	25	9	—	150	—	17,081	Of the iron oxides, 14,181 tons were 'Red Oxide,' and 2,900 'Brown Hæmatite.' In addition, 9,625 tons of 'spathose iron' and 86 tons of manganese ore. The pyrites was non-arsenical.
Newton Abbot	—	—	—	—	—	—	40 tons of manganese ore.
Newton St. Cyres	—	—	—	—	—	—	1,401 tons of manganese ore.
Peter Tavy	—	—	—	—	—	—	*See* Mary Tavy.
Plympton St. Mary	771	367	12,050	911	270	—	Of the pyrites, 210 tons were arsenical. In addition, 8 tons of zinc ore.
Rattery	—	—	—	—	—	4,400	'Brown Hæmatite.'

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TABLE II.—*continued.*

Parish.	Lead Ore.	Lead.	Silver.	Pyrites (Iron and Arsenical).	Arsenic Soot (and White).	Iron Oxides.	Miscellaneous Minerals.
	Tons.	Tons.	Ozs.	Tons.	Tons.	Tons.	
St. Stephen	—	—	—	—	—	—	Manganese, *see* Marystow.
Shaugh Prior	—	—	—	—	—	5,317	Mainly 'Brown Hæmatite,' 250 tons were 'Red Hæmatite.'
Sherwell	—	—	—	—	—	535	'Brown Hæmatite.' In addition, 55 tons manganese ore, *see* Bratton Fleming.
South Molton	80	60	64	—	—	—	
Stoke Gabriel	—	—	—	—	—	4,790	'Brown Hæmatite.'
Sydenham Damerel	100	69	947	—	—	—	140 tons Zinc ore. For Manganese, *see* Milton Abbot.
Tavistock	1,300	931	13,144	72,001	86,460	4,290	Of the pyrites, 50,393 tons were arsenical and 3,823 mixed 'crude arsenic and arsenical pyrites.' Oxides of iron as ochre and umber. In addition, 30 tons of wolfram and 60 tons of fluor-spar.
Ugborough	285	171	2,688	—	—	2,432	Of the iron oxide, 2,233 tons were 'Brown Hæmatite' and 199 tons ochre.
Walkhampton	—	—	—	—	2	—	
Whitchurch	12	7	—	152	—	—	Of the pyrites, 33 tons arsenical.
Wolborough	—	—	—	—	—	1,240	'Brown Hæmatite.'
Yealmpton	—	—	—	—	—	250	'Brown Hæmatite.'
Miscellaneous (unclassified)	740	565	2,575	—	—	—	160 tons of Manganese ore from 'Rostidyon' and 'Fullabrook.' 640 tons of iron ore from 'Furgam Mill' (? Brixham). The lead-ore is from 'Park,' 'South Maex,' 'True Blue,' 'Thomas United' and 'New Devon Consols.'

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Mr. FRANK MERRICKS, C.B.E., A.R.S.M.

Sir THOMAS MIDDLETON, K.B.E., C.B.

Mr. WILLIAM RUSSELL, C.B.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH,
16 and 18, Old Queen Street,
Westminster, London, S.W. 1.

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REPORT

OF THE

GEOLOGICAL SURVEY BOARD

FOR 1921

TO THE LORDS OF THE COMMITTEE OF THE PRIVY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

MAY IT PLEASE YOUR LORDSHIPS,

In accordance with our terms of reference, we, the Geological Survey Board, beg to submit our second Annual Report of the work of the Survey and Museum.

1. In our previous Report we referred to some of the economic aspects of the work of the Survey which could not be effectively dealt with unless the provision for systematic survey and revisions of survey were extended. We were then in a position also to report that on a complete statement of these matters, sanction had been given for a permanent increase of the establishment of the Survey amounting to half of that required for the full provision contemplated, and that this additional personnel had been secured.

Thus in the work of the past year it was possible to make a start on a programme drawn with a view to a material expansion of the area under survey. That programme, which was outlined in our last Report, has been followed, with the result that in the course of 1921 seven field units in all have been engaged on field work. A field unit, it may be noted, consists normally of a District Geologist with four Geologists; but the number of Geologists is varied where circumstances make some other arrangement desirable.

Four field units have been engaged on surveys previously in hand, viz. :—

(*a*) London and South Eastern District (primary six-inch survey).

(*b*) Midland District (primary six-inch survey).

(*c*) South-West Highland District (primary six-inch survey)—summer part of field season; and Ayrshire Coalfield Revision—remainder of season.

(*d*) North Highland District (primary six-inch survey)—summer part of field season; and Central Coalfield of Scotland Revision—remainder of season.

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Three field units have commenced re-surveys in areas for whi revision has long been overdue, viz. :—

(*e*) Northumberland and Durham District.
(*f*) Cumberland District.
(*g*) Lancashire District.

The re-survey work in Lancashire could not be taken u until late in the year, when the completion of certain work i North Wales and Shropshire set free geologists required for th establishment of the new field unit.

2. The Director's Report for 1921, which is presented herewith gives particulars of the field work which has been carried out in the year, with the related preparation and publication of maps and memoirs, the work of the Headquarters staff on petrological, palæontological and chemical questions. It also deals with the changes and developments in the collections and Library in the Museum of Practical Geology.

We are satisfied that in the past year the Survey has made good progress in the programme of field work, in the discussion and publication of the results of this work and in steadily accumulating and examining at Headquarters those examples and records obtained which bear on scientific and economic questions in British Geology.

3. As explained above, reference was made in our last Report to our recommendations for an addition to the staff; we then mentioned that authority had been given for an immediate addition to the personnel amounting to one-half of the full expansion contemplated. In the course of the year under report this authority was extended so as to provide for the full increase of staff originally proposed. Accordingly it has been possible to recruit four more geologists to the staff. There remain at present only four vacancies in this grade and it is anticipated that these vacancies will be filled this year.

4. Local headquarter offices have been opened as centres for the work of three areas, viz., in Newcastle for the Northumberland and Durham area: in Whitehaven for the Cumberland area and in Manchester for the Lancashire area. The requirements of the work in Scotland have outgrown the possibilities of the headquarters office there, but additional accommodation has been provided close by.

5. We have arranged for the Geological Survey to co-operate with the Fuel Research Board in their survey of coal seams from the fuel point of view. The work of this survey is to be carried out under local committees and the first of these has been established in the Lancashire area. The officers of the Geological Survey in that area will assist in bringing the available geological information into relation with the physical and chemical investigations carried on for the Fuel Research Board.

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6. At your Lordships' request we advised upon the revision of the salary scales of the scientific staff of the Geological Survey and Museum, and we reported that scales which have now been approved, while not in all respects such as would place the Survey permanently on a satisfactory basis, will suffice till 1924, when they are to be reconsidered.

7. The programme of field work for 1922 is—

(*a*) to prosecute the primary six-inch survey in continuation of the work of the past year in the London and South-Eastern District, in the Midlands, in the West Highlands, and in the North Highlands;

(*b*) to carry on revision of the six-inch surveys in Northumberland, in Cumberland, in Lancashire, in Ayrshire, and in the Central Coalfield of Scotland; also, if recruitment of staff permits, to make a beginning with the revision of the Fifeshire and Yorkshire Coalfields;

(*c*) to continue on the lines laid down last year (*a*) survey work bearing on metalliferous mining; and (*b*) the collection and examination of information obtainable from boreholes and other exploratory operations.

In view of the expansion which is taking place in the staff, the arrangements for work, not only in the field but also at headquarters, must at present be considerably influenced by consideration for the professional training of the new members of the staff.

F. G. OGILVIE,
Chairman.

May 1922.

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REPORT

OF THE

DIRECTOR

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1921

A district office was opened in November at 21, Albion Street, Gaythorne, Manchester, and placed in charge of Mr. W. B. *Wright*, District Geologist, who with three Geologists has carried on work during the past field-season in Sheet 76 (Rochdale), *thus* initiating the revision of the Lancashire coalfield.

There are also district offices in Whitehaven under Mr. Bernard *Smith* and in Newcastle-on-Tyne under Mr. R. G. Carruthers, from which the revision of the Cumberland and Westmorland *and* of the Northumberland and Durham districts was begun in 1921. Draughtsmen are attached to the Newcastle-on-Tyne *and* Whitehaven offices, but it has not yet been possible to provide one for the Manchester office.

The other districts in which mapping is in progress are the same as in 1920. In the West Midlands of England, the Shrop*shire,* Warwickshire and Staffordshire areas have been consolidated into one field district under the charge of Mr. T. C. Cantrill.

Special attention has been directed to collecting information about bores in progress both in England and in Scotland, and *many* cores have been inspected and checked by geologists.

The bores in search of petroleum in the Chesterfield, Mansfield *and* Staffordshire districts have been geologically examined and visits have been paid to the Kimmeridge Shale area in Norfolk *and to* the Kelham oil-boring. A complete series of samples from the Petroleum Department's bores is now preserved in the *Museum* of Practical Geology or in the Survey Office in Edinburgh.

A complete revision of the known British sources of barytes, *witherite*, manganese and tungsten has been in hand during the year and new editions of the Special Mineral Resources Reports

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on these minerals are in manuscript or in the press. Inform tion has also been collected regarding other mineral depo as occasion arose. The copper ores of England and Wales ha received special attention.

Advice and assistance in geological matters have been giv to many public departments.

A large number of enquiries on geology especially in r application to industry have been received from the gener public and commercial firms. The following are a few of th principal subjects: wells and bores for water; ironstone, pea concrete, oil-shale, soapstone, sands, coal, soils, mineral oi china-clay, sillimanite, gypsum, roadstones, setts, copper and lea ores, barytes, brick clays, precious stones.

(1)—ENGLAND AND WALES

Field Survey on the six-inch scale

London District.—Field survey was continued in Sheets 239 (Hertford), 256 (North London), 271 (Dartford), and commenced in Sheets 257 (Romford), 272 (Chatham), 287 (Sevenoaks) and 288 (Maidstone) by Dr. Sherlock, Mr. Bromehead and Mr. Dines, with Mr. Dewey as District Geologist.

Shropshire, Warwickshire and Staffordshire District.—Work was continued in Sheets 138 (Wem), 139 (Stafford), 151 (Welshpool), 152 (Shrewsbury), 153 (Wolverhampton), 167 (Dudley) and 168 (Birmingham) by Messrs. Wedd, Dixon, Sherlock, Pocock, Whitehead and Robertson, under the superintendence of Mr. Cantrill, District Geologist.

Lancashire District.—Work was commenced in Sheet 76 (Rochdale) by Mr. Wright, District Geologist, and Dr. Sherlock, Mr. Wray and Mr. Lloyd.

Cumberland District.—Sheets 17 (Carlisle) and 28 (Whitehaven) were commenced by Messrs. Dixon, Eastwood, Maden, and Trotter, under the superintendence of Mr. Bernard Smith.

Northumberland District.—Work was commenced in Sheets 1 (Norham), 2 (Berwick), 3 (Ford), and 4 (Holy Island) by Mr. R. G. Carruthers, District Geologist, with Messrs. Dinham, Burnett, Marsden and Fowler.

In preparation for the publication of a New Series colour-printed edition of Sheet 313 (Shaftesbury), Mr. Dines and Mr. Hollingworth under the superintendence of Mr. Howe, have revised the boundaries of certain formations within that sheet.

Indoor Work

The manuscripts of the following memoirs are being written or edited for publication:—

Special Reports on the Mineral Resources of Great Britain:—

Tungsten and Manganese Ores, 3rd Edition (Vol. 1).
Lead and Zinc Ores of the Pennines, Part I. Northumberland and Alston Moor.
Lead and Zinc Ores of the Pennines, Part II. Yorkshire, etc.
Copper Ores of the West of England.
Copper Ores of the Midlands, the Lake District, and North Wales.
Refractory Materials: Fireclays. Chemistry and Physical Tests.
Water Supply of Wiltshire.
Water Supply of Gloucestershire.
Palæontological Monograph on Carboniferous Plants. Parts I and II.

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A complete revision of the known British sources of barytes, witherite, manganese and tungsten has been in hand during the year and new editions of the Special Mineral Resources Reports

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Vol. XXI.—Lead, Silver-Lead and Zinc Ores of Cornwall, Devon and Somerset. By H. Dewey. 72 pp.; 18 text-figures. 1921. Price 2*s.* 6*d.* net.

Vol. XXII.—The Lead and Zinc Ores of the Lake District. By T. Eastwood, A.R.C.S. 56 pp.; 1 plate; 4 text-figures. 1921. Price 2*s.* net.

A Short Account of the Geology of the Isle of Wight. By H. J. Osborne White, F.G.S. 219 pp.; 1 plate; 43 text-figures. 1921. Price 10*s.* net.

The Water Supply of Norfolk from Underground Sources. By W. Whitaker, B.A., F.R.S. 185 pp. 1921. Price 10*s.* net.

The Water Supply of Buckinghamshire and Hertfordshire from Underground Sources. By W. Whitaker, B.A., F.R.S. 368 pp. 1921. Price 16*s.* net.

The Geology of the South Wales Coalfield. Part XIII. The Country around Pembroke and Tenby. (Explanation of New Series Sheets 244 and 245.) By E. E. L. Dixon, B.Sc., F.G.S. 220 pp.; 5 plates; 13 text-figures. 1921. Price 8*s.* net.

The Geology of South London. (Explanation of New Series Sheet 270.) By Henry Dewey and C. E. N. Bromehead, B.A. 92 pp.; 3 plates; 1 text-figure. 1921. Price 3*s.* net.

In the press.

Special Reports on the Mineral Resources of Great Britain:—

Vol. II.—Barytes and Witherite. *Third Edition.*

Vol. XX.—Lead and Zinc. The Mining District of North Cardiganshire and West Montgomeryshire.

Vol. XXIII.—Lead and Zinc Ores in the Pre-Carboniferous Rocks of West Shropshire and North Wales.

The Water Supply of Cambridgeshire, Huntingdonshire and Rutland from Underground Sources.

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(2)—SCOTLAND

Field-work

In Scotland each field unit as in previous years has spent part of the season in revising the maps of the coalfields and part in the primary survey of the Highlands.

Coalfield Revision.

Ayrshire.—Mr. E. B. Bailey, District Geologist, with Messrs. Anderson, Richey, Eyles and Simpson have continued survey work in Sheets 30 (Renfrew), 22 (Kilmarnock) and 14 (Ayr).

Lanarkshire, Clackmannanshire and Stirlingshire.—Mr. M. Macgregor, District Geologist, with Messrs. Wilson, Read, Haldane and Ross have continued the revision of Sheets 23 (Lanark) and 39 (Stirling).

Primary Survey.

West Highlands.—Work was commenced in Sheets 52 (Ardnamurchan) and 51 (Coll), by Messrs. Richey, Eyles and Simpson, under the superintendence of Mr. E. B. Bailey. Dr. G. W. Lee has examined the fossiliferous Secondary rocks.

North Highlands.—Mr. M. Macgregor, District Geologist, has been assisted by Messrs. Wilson, Read, Haldane and Ross in the survey of Sheet 102 (Lairg, Sutherlandshire).

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Indoor Work

The manuscripts of the following memoirs are being written or prepared for publication :—

Explanations of Sheets 84 (Nairn), 86 and 96 (Portsoy, Huntly, Banff), 44 (Oban and Mull), 54 (Moor of Rannoch).
The Cannel Coal, Lignite and Mineral Oil Resources of Scotland.
The Ayrshire Bauxitic Clay.
Economic Geology of the Central Coalfield of Scotland :—
Area VI. (Bathgate).

The following maps and memoirs have been published or are passing through the press :—

I.—MAPS

Published.

¼ inch to 1 mile :—

Sheet 6 (Caithness), Sheet 13 (Islay).

1 inch to 1 mile :—
Sheet 53 (Glencoe), Sheet 81 (Raasay and Applecross).

6 inches to 1 mile :—
Dumfries, 7 N.W.
Edinburgh, 10 N.E., S.W., S.E.
Lanark, 3 S.W.; 5 S.E.; 8 S.E.; 9 N.W., N.E., S.E.; 11 S.E.; 12 N.W., N.E., S.W., S.E.; 13 N.W., N.E.; 17 N.W., S.E.; 19 S.W.; 20 N.W., N.E., S.W., S.E.; 23 N.E., S.E.; 24 N.W., N.E.; 25 N.E.; 31 N.E.; 49 N.E., S.E.

Linlithgow, 3 S.W. (2nd Edition); 5 N.W., N.E., S.W., S.E.; 7 N.W. and S.W. (2nd Edition); 8 N.E., S.E.; 9 N.W., N.E. (2nd Edition), S.W., S.E. (2nd Edition); 10 N.W. (2nd Edition), S.W. (2nd Edition); 11 N.E., S.E.; 12 N.W., S.W.
Renfrew, 8 N.W., N.E., S.W., S.E.; 12 N.W.
Stirling, 24 S.E.; 28 N.E.; 30 N.W., N.E., S.W., S.E.; 31 N.W., S.W.; 32 N.W.; 34 (Dumbarton det.) N.W.; 35 N.W., N.E., S.W., S.E.; 36 N.W.

In the press, engraving or colour-printing.

1 inch to 1 mile :—

Sheet 37 (Mid Argyll), Special Map of Assynt District, Sheet 86 (Huntly), Sheet 96 (Banff), Sheet 54 (Rannoch Moor), Sheet 31 (Falkirk) (New Edition), Sheet 16 (Moffat) (New Edition), Sheet 44 (Mull).

6 inches to 1 mile :—

Lanark, 8 S.W.; 9 S.W.; 11 N.E.; 13 S.W., S.E.; 14 S.W.; 16 N.E.; 17 N.E., S.W.; 18 N.E., S.W.; 24 S.W., S.E.; 25 N.W.
Renfrew, 7 N.E., S.E.; 11 N.E., S.E.; 12 S.W.; 16 N.W., N.E.; 17 N.W.
Ayr, 8 N.E., S.E.; 11 N.E., S.W., S.E.; 12 N.W.; 16 N.W. and S.W., N.E., S.E.; 17 S.W.
Stirling, 25 S.W.; 28 S.E.; 29 N.W., N.E., S.W.

Copies of the following six-inch sheets, which are not to be published were deposited in the Office for public reference :—

Argyll, 52; 66 S.E.; 67; 69; 80 N.E., S.W.; 81; 82; 83; 93 N.W., N.E.; 122.
Ayr, 7 N.W., S.W. (New Series).

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II.—MEMOIRS

Published.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1920. *See* p. 7.

Description of Arthur's Seat Volcano. By B. N. Peach, LL.D., F.R.S. Second Edition. 26 pp.; 1 plate; 4 text-figures. 1921. Price 2*s.* 6*d.* net.

The Economic Geology of the Central Coalfield of Scotland:—
Area IX.—Carluke, Strathaven and Larkhall. By L. W. Hinxman, B.A., F.R.S.E., R. G. Carruthers, F.G.S.; M. Macgregor, M.A., B.Sc. and C. H. Dinham, B.A. 148 pp.; 6 plates; 2 text-figures. 1921. Price 8*s.* net.

Special Reports on the Mineral Resources of Great Britain:—
Vol. XVII.—The Lead, Zinc, Copper and Nickel Ores of Scotland. By G. V. Wilson, with contributions by John S. Flett, LL.D., F.R.S. 159 pp.; 2 plates; 16 text-figures. 1921. Price 7*s.* 6*d.* net.

PETROGRAPHICAL DEPARTMENT

Dr. Thomas has been engaged on the petrography of Sheets 44 (Mull), 14 and 22 (Ayrshire and Renfrewshire), 42 (Tiree), 43 (Iona) and 51 (Ardnamurchan).

600 rock sections were cut, of which 460 were Scottish, 128 English and 12 foreign and miscellaneous; 121 rock specimens were collected in Scotland from districts in which the geologists are surveying.

Descriptions of 354 rocks have been issued to the geologists engaged on field work.

The Petrographer has answered many enquiries received from Government departments and from the public.

PALÆONTOLOGICAL DEPARTMENT

From Shropshire, Cumberland and Somerset, principally, 4,594 fossils were collected during the year. The officers of the department have given much assistance in examining the cores of deep borings and determining horizons by the fossils obtained. Mr. Pringle has made a number of visits to various districts in North Wales, Dorsetshire, Wiltshire, Bedfordshire, etc., where special palæontological knowledge was required. Mr. Chatwin has been employed mainly in revising the Museum collections. Dr. Kitchin has been engaged on an investigation of the fossils of the Secondary rocks of Kent.

In Scotland 3,355 fossils were collected from borings and from natural exposures; many were obtained from the Brora area in Sutherlandshire by Dr. Lee and the fossil collectors.

CHEMICAL DEPARTMENT

Analyses have been made of 24 igneous and metamorphic rocks from Aberdeen, Banff and Mull, and of 14 fireclays. Partial analyses were also made of 2 Scottish iron ores, and the chemistry of the Strathmore meteorite was specially investigated by Mr. Ennos.

PHOTOGRAPHIC WORK

A large series of photographs was taken in the Isle of Wight, the London district and the Midlands. The new landscapes added to the collection number 356. More than 100 photomicrographs, enlargements, lantern-slides and diagrams were made for special purposes. The prints necessary for the photographic albums of English views have been prepared.

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In Scotland 89 views of geological interest were photographed in Mull, Iona and Staffa and the Lothians. The album of photographic prints is complete to the end of 1920.

The sale of prints and lantern-slides to the public during the year was: English, 336 prints and slides; Scottish, 338 slides, 38 prints and 2 enlargements.

MUSEUM OF PRACTICAL GEOLOGY

During the year 1921 the total number of visitors to the Museum has been 26,829; of these 21,845 visited the Museum on week-days in the day-time and 2,637 in the evenings; the number of Sunday visitors was 2,347.

Fifty-five demonstrations to schools and institutions have been given in the Museum during the year, the aggregate attendance being 1,090.

The London Model has been recoloured in accordance with the new six-inch geological maps, and a case of specimens, arranged to illustrate the stratigraphy and economic geology of the London district, has been placed on exhibition beside it. Progress has been made in the expansion of the economic collections and cases have been arranged to illustrate the uses of refractory materials, abrasives, sands and cements.

The collection of roadstones has been transferred to another case and rearranged and the space so liberated is being devoted to an exhibit of recent Survey maps and publications.

In the Mineral Department a series of six cases has been prepared to illustrate the Special Reports on Iron Ores, Volumes VIII to XII, dealing with the Hæmatite Ores of Cumberland and the Forest of Dean, Sundry Unbedded Ores and the Bedded Ores of the Lias and Oolite.

The cleaning and registration of specimens in the older part of the collection has been continued. Wall-cases 10 to 16, and 53 to 56, and Pedestal Cases 31 and 32 having been dealt with.

Twelve divisions of the Horseshoe Case have been cleaned and relined.

Collection and investigation of the British iron ores have been proceeded with, and the Frodingham and Cleveland Districts have been visited for this purpose.

The Library and Map Room have been used by the public and officials of other Departments in increasing numbers. The additions during the year comprise 182 volumes of independent works, 2,215 volumes and parts of serial publications, 536 maps, not including those bound in the foregoing, and 192 pamphlets. Author and Subject cards were typed for the above, and added to the Card Catalogue, and a number of worn cards were replaced.

The presentations during the year include a collection of papers, issued by the Geophysical Laboratory of the Carnegie Institution, Washington, and publications from the recently established Geological Surveys of Greece, Poland, Czecho-Slovakia, China, Sierra Leone, Nigeria and Uganda.

JOHN S. FLETT,
Director.

3rd March, 1922.

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List of Donations during the Year 1921

Ashcroft, F. N., Esq.—Three specimens of calcite, one specimen of pearl spar, two specimens of blende, New Glencrieff Mine, Wanlockhead. Specimen of lignite partially silicified, from Ireland. One cut ruby spinel, and one crystal of pennine from Zermatt, Switzerland.

Bailey, E. B., Esq., M.C., B.A.—Twelve micro-sections of rocks from Yorkshire.

Banfield, —., Esq.—Specimen of marcasite from River Adur, Shoreham.

Berry, James, Esq.—*See* Pistor.

Carley, George C., Esq.—Specimens of native sulphur with selenite from Girgenti, Sicily. A finely crystallised specimen of pyrite, from Ravi, Tuscany.

Carr, R. H., Esq.—A series of bauxite samples from the Three Friends Mine, Akyma, Demerara River, British Guiana; and one sample from the Surinaamsche Bauxite Maatischappij, Dutch Guiana.

Chatterton, F., Esq., F.R.I.B.A.—A specimen of *Stigmaria* from the Carboniferous rocks, bank of River Coquet, near Harbottle, Northumberland.

Clark, F. B., Esq.—A well preserved specimen of *Productus* of the group of *P. semireticulatus* (Martin), from the Coal Measures (near the Four Foot Coal), Aldridge Colliery, near Walsall.

Cole, R. Langton, Esq., F.R.I.B.A.—Series of negatives of photographs of geological interest made by the late J. J. Cole, Esq.

Cripps, A., Esq.—Serpentine powder from a well in Latakia, Syria.

Davis, A. G., Esq.—A specimen of *Melanopsis ancillaroides* (Desh.) from the Blackheath Beds of Charlton, Kent, figured by Dr. L. Dudley Stamp, *Proc. Geol. Assoc.*, vol. XXXII, part 2, 1921, pl. ii., fig. 8.

Duckworth, H., Esq.—Sett of Haslingden Flag, "Rosendale Granite."

Eastwood, Frank B., Esq.—Two specimens of native gold from the St David's Mine and the Gwyn Mine, Merionethshire, respectively.

Gotham Company, Ltd., Messrs. The.—One alabaster bowl, one alabaster ash-tray and one alabaster slab, from Chellaston, Derby.

Gordon, H. S., Esq.—Monazite concentrates.

Gregory, Prof. J. W., F.R.S.—A specimen of *Rhaxella*-chert from the High Level Gravels (280 ft. above O.D.) in the upper Roding valley above Loughton, Essex.

Griete, Captain.—A series of mineral specimens from Brazil.

Hort, Gilbert, Esq.—Specimen of columbite from Namaqualand.

Hubbard, Theodore, Esq.—Specimen of native silver in a small vein of galena, blende and pyrite, with quartz.

Hutchinson, T. Anthony, Esq.—A series of samples of fire-resisting and filter bricks made largely of diatomaceous earth.

Johnstone, J., Esq., B.A., M.B., F R.C.S.—A specimen of gneiss showing glacial striæ and the effects of sea erosion.

Leese, J., Esq., M.A., Mus.B.—A small set of fossils from the Shineton Shales and a specimen of *Collyrites* from the Coral Rag of Upware, Cambridgeshire.

Lindsay, L., Esq.—Native tellurium from Colorado.

Mallett, Francis, Esq.—Two fine specimens of cut sapphire.

Matley, Dr. C. A.—Fifty-two micro-sections of rocks from the Lleyn peninsula, Carnarvonshire.

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MORLEY, E. H. E., ESQ.—Specimen of tin-ore from Katanga, Central Africa.

NOBLE AND COMPANY, MESSRS.—A specimen of facetted hæmatite.

O'DRISCOLL, FLORENCE, ESQ.—Cut tourmaline.

PALAGI, THE CONTE.—Specimens of anthracite from Sardinia, Italy.

PISTOR, M. LE GÉNÉRAL (per JAMES BERRY, ESQ.).—Specimen of selenite with sand ("rose-du-sable"), from the Sahara, at Bir Pistor, near Ghadames, South Tunisia.

POULAIN, A., ESQ. (per J. PRINGLE, ESQ.).—Six polished specimens of French marbles.

RAISIN, MISS C. A., D.Sc., F.L.S., F.G.S.—A series of 50 choice invertebrate fossils of various groups and ages.

REID, ALEXANDER, ESQ., M.INST.C.E., F.G.S.—A specimen of pitch from Wrentnall, Salop.

RILEY, COL. J. H. C.—Specimens of chromite, from Blomidon Mountain, York Harbour, Newfoundland.

RUTHERFURD, W. G., ESQ.—Specimen of verdite from South Africa.

SANDISON, W. G. W., ESQ.—Three specimens of uvarovite, from Hagdale, Unst, Shetland. Two samples of concentrates from Chromite Mine, Hagdale. A specimen of brucite, from Hagdale Bay, Shetland.

SAWYER, A. E. T., ESQ.—Five specimens of *Terebratula* and two of *Corynella* from the Inferior Oolite of Gloucestershire.

SCHAVERIEN, J., ESQ.—Rough beryl and tourmaline and a polished specimen of opal.

SHEPPARD, T., ESQ., M.Sc., F.G.S.—A token, issued by Henry Sneaton in 1667, bearing the device of three "snake-stones," the arms of Whitby.

SIMMONS, G. W., ESQ.—A set of 49 microscopic sections, chiefly of Carboniferous Limestone with corals from the Avon Gorge, Bristol.

SPATH, DR. L. F., F.G.S.—A series of 80 fossils (chiefly lamellibranchs, gasteropods and brachiopods) from the nodules of the Tardefurcata Bed near Leighton Buzzard.

STARTIN AND COMPANY, MESSRS.—A specimen of phlogopite from Madagascar, also a specimen of manganese ore from Western Australia.

STREATFEILD, H., ESQ.—A specimen of fossil wood from the Lower Greensand, and ammonites from the Lower Gault, of Covers Brickyard, Westerham, Kent.

WHITE, FRANKLIN, ESQ., M.I.M.M.—A series of specimens of villamaninite, etc., from the Providencia Mine, Leon Province, Northern Spain.

WIGG, CARLOS, ESQ.—Two specimens of manganese ore from the Wigg Mining Estate, Minas Geraes, Brazil

WIGHT, MISS.—Specimen of banket from South Africa.

WILLIAMS, C. J., ESQ., I.S.O.—Iron ore of Ordovician age, containing bituminous matter, from Llandegai, Bangor, North Wales.

WILSON, H. A., ESQ.—Specimens of vogtite from a steel-furnace slag

WILSON, H. W., ESQ., B.A.—Casts of footprints of *Iguanodon* from the Wealden (Hastings Beds) of Galley Hill, Hastings.

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In the Lancashire district Mr. Wright and his staff have begun the revision of Sheet 76 (Rochdale), which includes part of the northern margin of the Lancashire coalfield. The geology though apparently of a simple type is really more complicated than would be imagined at a first glance. Yoredale rocks (Pendleside series) and Lower Coal Measures occupy most of the country and include four beds of grit which are separated by shales. The identification of the grits in various parts of the district, and their correlation, are being carefully studied as there is an important set of faults bringing various horizons sharply against one another. Several coal seams exist in this series, the principal being the Arley Mine, and since the original geological survey was made a good deal of mining has been done, usually at no great depth. The physiographic features of the district are interesting, as parts of it apparently have not been glaciated and a thick covering of rotted debris or "head" covers the surface of the grits on many of the higher moors.

The report on the mapping of the Cumberland district by Mr. Smith and his staff contains several points of interest. They have been working in two districts, one near Whitehaven, where the principal coal mines occur, and the other north and west of Carlisle. The Whitehaven coalfield is known to be intensely faulted and the thickness and sequence of the beds are variable, and are not completely known; much caution accordingly is necessary in drawing conclusions regarding the geological structure. Mr. Dixon, however, has arrived at an interpretation of the succession in the Carboniferous Limestone that is in accordance with the work of previous observers. Much study has been devoted to the records of bores and the mining plans, to which access has been freely permitted, and the sequence, though variable, has been elucidated in its main features. It seems probable that the Upper Red Measures (represented by the Whitehaven Sandstone) rest unconformably and transgressively on the productive measures, and are in turn unconformably overlain by New Red Rocks.

Both in the Whitehaven and in the Carlisle districts the New Red (including the well-known St. Bees Sandstone) is of great importance. These beds are almost unfossiliferous, though at their base a magnesian limestone occurs that contains mollusca of Permian types; and the question is by no means settled whether the breccias, red sandstones and marls are all to be assigned to one geological period or include representatives of the Triassic system in addition to the Permian.

The glacial geology of North Cumberland is exceedingly complicated, and the mutual relations of local ice-sheets and the larger body of ice that invaded the district from the Irish Sea (ultimately in large part of Scottish origin) are often difficult to unravel. Mr. Dixon furnishes a very interesting account of the conditions at a late stage in the Glacial period in the neighbourhood of Ennerdale where temporary lakes were held up by dams o

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ice and fans of deposit were laid down by streams entering the lakes from the hills on each side.

The Solway raised beaches and river terraces have also received careful investigation. They are of slight elevation (the highest being about 33 feet above H.W.M.), and contrast rather strongly with the raised beaches of Galloway and the Firth of Clyde, which rise to heights of 100 feet. The relations of these beaches to the glacial phenomena, and the exact period of their formation, remain still to be defined.

In Northumberland Mr. Carruthers and his staff have surveyed a large area in the extreme north of the county. The strata are of Lower Carboniferous age (with the exception of the Cheviot lavas, which are Lower Old Red Sandstone) and form a very interesting transition from the Cementstones and Calciferous Sandstones of Scotland to the Carboniferous Limestone type of the Pennines. At the base there is a well-marked Cementstone (Tuedian) Group, which is estimated to form a series not less than 2,000 feet thick, and is well seen in Tweedside above Berwick. Above this is the great Fells Sandstone, a well-marked and characteristic horizon. The Scremerston Coals succeed, and contain from four to seven coals of rather inferior quality. Mr. Carruthers holds that there are large reserves of these coals that may yet prove of commercial importance. The Limestone Group of North Northumberland is equivalent to the Lower Limestones of Scotland, together with practically the whole of the Oil Shale Group of that country. The excellent work of Mr. Gunn, who mapped these rocks for the original survey, has been generally confirmed by the revision, but a careful study of the lithological and palæontological features of the individual beds is being made and as a consequence several changes in the mapping have proved necessary, some of them having an important economic bearing.

In Scotland, Mr. Bailey and his staff have continued the revision of the Ayrshire coalfield and have introduced some important changes in the maps of that district. The lavas of Millstone Grit age near Tarbolton have been proved to have a more extensive outcrop than was hitherto suspected, but the valuable Ayrshire Bauxitic Clay which accompanies these rocks in North Ayrshire has not yet been found in a workable state on the south side of the Kilmarnock coalfield. The north edge of the concealed coalfield of Central Ayrshire is shown to have a very complicated structure, and the relations of the New Red Sandstone lavas and sediments to the underlying Coal Measures are being carefully scrutinised.

The revision of the Central coalfield is now completed, and the 6-inch maps are either published or in the press. The rocks surrounding the coalfield are now being surveyed, and the maps of the outlying coalfields of Muirkirk and Douglas are undergoing revision. Starting from the underlying platform of Silurian and Old Red Sandstone rocks, Mr. Wilson has commenced

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the mapping of the Calciferous Sandstones and Carboniferous Limestone of the Muirkirk field. He has noted also the extensive deposits of glacial sand and gravel which are a conspicuous feature of this district and are to be assigned to the action of the waters discharged from melting ice-sheets at a late stage in the Glacial period. Temporary glacial lakes were formed at various elevations and drained south-eastwards into the Douglas valley by a well-defined series of overflow channels. The Douglas basin, though small, is exceedingly complicated in structure, and contains valuable coal seams. Numerous bores are being made in search for coal, and have been examined and reported on in previous "Summaries of Progress." The revision of this area was started before the war, and is now being resumed.

The Stirling and Alloa coalfields, which link the Central coalfield with that of West Fife, are being re-examined under Mr. Macgregor as District Geologist. Mr. Read has found reason to believe that the Abbey Craig sill is intruded into the Limestone Coal Series, and beneath it there is a considerable thickness of the Lower Limestones. This sill in a district four or five miles to the south-west is believed to be at a horizon about 600 feet lower. The revision of the Alloa and Clackmannanshire coalfield is making progress, and the lower portion of the Coal Measures sequence is now more adequately understood.

The only bore in search of oil under the direction of the Petroleum Department which is now being actively prosecuted is at D'Arcy in Midlothian. It starts near the base of the Scottish Carboniferous Limestone and penetrates rocks of Calciferous Sandstone age, including the oil-shale measures of the Lothians. This series had not hitherto been much explored by borings on the east side of the Dalkeith coalfield, and the bore is consequently of considerable interest from a purely geological standpoint, apart from its importance as a test of a well-marked anticlinal structure and a possible source of liquid petroleum.

In the West Highlands Mr. Bailey and his staff were engaged during part of the year in mapping the metamorphic and igneous rocks of Ardnamurchan and Coll. The Tertiary volcanic mass of the Ardnamurchan peninsula has a most complicated structure, and not more than one half of it has yet been examined by the Survey. It proves to have many points of resemblance to the central area of igneous rocks in Mull. The island of Coll consists of Lewisian sedimentary and igneous gneisses, of which the latter seem to be clearly intrusive into the former. An outcrop of the Raasay Ironstone has been observed at Kilchoan, in Ardnamurchan, but, like all other outcrops of this seam except those in Raasay, there is little prospect that it will prove of economic value.

A large area of metamorphic rocks in Sheet 102 (Lairg), principally of regular Moine types, has been surveyed during the summer months by Mr. Macgregor and his staff. Into this series there have been intruded dykes of lamprophyre and several

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masses of granite, the latter showing occasionally at their margins that they have permeated and in some measure absorbed the surrounding schists. Hornblendic rocks also occur, presumably of igneous origin, and a mass of scyelite or allied rock has been reported near Loch Shin by Mr. Ross.

II.—FIELD WORK

(A)—ENGLAND AND WALES

1. London and South-Eastern District

H. Dewey, District Geologist.
R. L. Sherlock, D.Sc., A.R.C.Sc.
C. E. N. Bromehead, B.A.
H. G. Dines, A.R.S.M., A.M.I.C.E. } Geologists.

During the early months of the year Mr. H. G. Dines was engaged upon the revision of the Tungsten and Manganese Ores Memoir. He visited the mines where these ores are raised in Cornwall, Devon and North Wales. In the autumn Mr. Dewey visited Cornwall in order to bring up to date the information regarding certain of the tungsten mines. The MS. for the third edition of this memoir is in an advanced stage.

Messrs. Wilson, Eastwood, Pocock, Wray and Robertson were engaged upon the revision of the memoir dealing with Barytes and Witherite. All the mines and workings were visited. The third edition is now passing through the press and will shortly be published.

In the London District the mapping has been continued in Sheet 271 (Dartford). Mr. Bromehead surveyed the Chalk area and the underlying beds in Kent, and Mr. Dines the Tertiary beds and the Pleistocene formations of a small part of Essex. The survey of this Sheet is complete.

Dr. Sherlock was engaged for a few weeks in finishing the survey of Sheet 239 (Hertford). He mapped a small, but economically important, area in the Lea valley north of Waltham Cross.

CRETACEOUS

Mr. Bromehead finds that in the area shown in the south-eastern corner of the Dartford Sheet, which includes a part of the Chalk escarpment of the North Downs, the oldest stratum exposed is the upper part of the Folkestone Beds, the topmost division of the Lower Greensand. It consists of yellow sands with some seams markedly glauconitic and others cemented by silica or lime. The well-known Ightham or Oldbury stone is a glauconitic band thus cemented. The siliceous or cherty beds show hollows usually regarded as casts of sponge spicules, but a calcrete band at Parson's Corner, near Birling, is found to be a felt of small spines belonging apparently to echinoderms. The

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junction of the Folkestone Beds and the Gault clays is abrupt, the base of the latter being a glauconitic bed full of phosphatic nodules. These nodules render the boundary easy to trace in the field, in contrast to that between the Gault and the Lower Chalk, which is a gradual passage, frequently traceable only by the downward limit of lime-loving plants such as *Clematis* and *Campanula*. The Gault is not on the whole fossiliferous; in a deep pit near Paddlesworth belonging to the Portland Cement Companies no fossils were detected. The basement bed and the clays immediately above it have, however, yielded both *Douvilleiceras mammillatum* and *Hoplites*.

The Upper, Middle and Lower divisions of the Chalk have been mapped, usually with some certainty, along the escarpment and in the deeper valleys which dissect the dip-slope. Both lithological and palæontological evidence is available for this purpose; the base of the Middle Chalk is marked by a hard nodular band, the Melbourn Rock, below which lies the soft Belemnite Marl, some 18 inches thick. In the great chalk pits near Snodland the marked contrast between these two beds makes the limit between the divisions very clear. In the mouth of the Medway Gap the Middle Chalk gives rise to a subsidiary dip-slope and escarpment, whereas further west the whole Chalk formation forms a single topographic feature of this nature. It has been remarked by Mr. Hilaire Belloc that the Pilgrim's Road ndicates roughly the upward limit of cultivation towards the chalk scarp. The prehistoric trackway is for the most part, in this district, on the Melbourn Rock, cultivation being practically confined to the more marly Lower Chalk.

The base of the Upper Chalk is also clearly indicated. The *Reussianum* fauna has been detected in every exposure of the horizon, and the Chalk Rock type of sedimentation can be traced throughout the district, since fragments of the hard nodular chalk are scattered over open down-land, wooded belts and arable areas. The zones present in all exposures have been determined, the fossils collected being submitted to Mr. Chatwin. Mr. Osborne White has discussed the distribution of the zones over much of the area surveyed[1]; the new work amplifies but is nowhere discordant with his conclusions.

TERTIARY

The Tertiary beds are not of themselves of great interest, but important facts as to their relationship with each other and with the Chalk have been established. In the north-eastern part of the area the whole series up to the London Clay is present in the Shorne outlier. Much of this ground is heavily wooded, rendering the exact boundaries difficult to define; while the absence of contours and levels on the six-inch maps makes estimates of thickness precarious. The Thanet sands are certainly thinner on the south side of the outlier than they are further

[1] *In* 'Ightham—the Story of a Kentish Village,' by F. J. Bennett, 1907, Appendix II., pp. 119-126.

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west; the Woolwich Beds are apparently normal, the shell bed being exposed at the side of Watling Street—a little to the west of St. Thomas's Well, and on the flanks of the *Oppidum* in Cobham Park. The Blackheath Beds are of the usual pebbly type and at least 20 feet thick, in marked contrast with the poor development at Swanscombe. At Soulers Hill the Blackheath Beds are fossiliferous and yield the characteristic *Pectunculus plumsteadiensis*, Sow. At Cobham Hall the Thanet Sand does not exceed 40 feet; at Cobhambury Wood there is a small outlier, capped by Woolwich Beds, in which the Thanet Sand is only some 10 feet thick. Further south, at Camer, Meopham, Ridley and Ash we find small outliers of Woolwich Beds resting directly on the Chalk. Still nearer the scarp there are outliers of Blackheath Beds at Holly Hill, Stansted and Knockmill again resting directly, as far as can be ascertained, on the Chalk. It is, therefore, clear that in this district, as in that a few miles to the west,[1] there is a true overlap of the Thanet Sand by the Woolwich Beds, and of the latter in turn by the Blackheath Beds. The dip-slope of the Chalk must have been in existence at the beginning of Eocene times, but there is also some new evidence to show that the Chalk had been thrown into minor folds before this plane, on which the successive members of the Eocene system rest, was cut. This pre-Eocene surface is approximately that on which the Clay-with-flints lies. The deposit to which that name is given consists, everywhere in the district, to a large extent and sometimes almost wholly, of Tertiary debris. In fact the distinction between Tertiary beds in place and Clay-with-flints is somewhat vague. Where the Tertiary material is much disturbed, or is a mixture of two or more divisions, it has been mapped as Clay-with-flints, but where a recognisable division, with indications of the original bedding, is visible, an outlier is shown on the map. The boundaries of these outliers are usually uncertain; a hillock rising above the general level may be composed of clean Woolwich Beds, as at Ridley, but it fades off gradually into the thin layer of resorted material with which relics of other beds of Eocene date, chalk-flints, and other components are merged. Owing to the paucity of sections some outliers which ought to be shown on the map may have escaped detection.

The surface of the Chalk falls gradually from the escarpment, where it is about 700 feet above O.D., to the Thames, but the dip of the beds is in the same general direction at a slightly higher angle. At the escarpment the Clay-with-flints rests for the most part on the Zone of *Holaster planus*, often on the *Reussianum* band. The Zone of *Micraster cortestudinarium* comes on about the latitude of Stansted, that of *M. coranguinum* towards Ash and Meopham Green. In the south-east corner, however, these higher beds come on at the escarpment. Near Trosley Towers only the *Reussianum* band is present; the pits

[1] 'Summary of Progress' for 1914 (*Mem. Geol. Surv.*), 1915, p. 28.

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at the southern edge of Whitehorse Wood show at least 35 feet of the *H. planus* Chalk, while the road-cutting north of Birling Place includes a considerable thickness of the *M. cortestudinarium* Zone and the Holly Hill outlier of Blackheath Beds probably rests on the *M. coranguinum* Chalk. This on-coming of higher zones as the Medway is approached suggests that the syncline in which that river flows was at any rate initiated in pre-Tertiary times.

Dr. Sherlock notes that between Hoddesdon and Enfield Lock, in the Lea Valley, a marked difference is noticeable between the two sides of the valley. The west side is mantled by glacial and river deposits down to the alluvial flat, but on the east side the London Clay crops out and drift is only met with about 2 miles back from the alluvium. On this side the country is broken into hill and dale, in marked contrast to the usual flat London Clay topography. Boulder clay caps the hills, about 200 feet above river level, and it is clear that there has been considerable erosion since glacial times.

The difference between the two sides of the valley has an economic aspect which does not seem to have been sufficiently appreciated. The Lea Valley is the chief centre in this country of nursery gardens, which cover a large part of the river brick-earth and gravels, and they obtain an ample supply of water from shallow wells on the west of the valley. The industry is still expanding and many of the new nurseries are built on the east side, on London Clay. In these cases the large firms obtain water from deep wells sunk to the Chalk, but others are dependent on rainwater collected from the roofs and this supply is liable to fail in a dry season.

PLEISTOCENE

Mr. Dines reports that in the neighbourhood of Grays, Essex, there are several sections which show the relation between the Coombe Deposits[1] and the Thames valley gravels. Coombe Deposits and Flood-plain gravel can be seen in the new cutting south of the Portland Cement Company's quarry south of Belmont Castle, and west of Grays Thurrock. At the northern end of the cutting, 10 feet of hard cemented rubbly chalk, the type of Coombe Deposit known as Coombe Rock, rests on the Chalk, but as all the overburden has been removed from the chalk quarry, its former northerly extension cannot be ascertained. Its southern boundary, which trends nearly east and west, forms a cliff about 170 yards north of Askew Farm. Resting against and partly undercutting this cliff is a deposit of dark-brown sand and clay extending along the cutting as far as Askew Farm. Where it rests against the Coombe Rock it consists chiefly of sand, which is locally stratified, containing a few thin beds of pebbles and sub-angular flints. These can

[1] 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, pp. 8, 9.

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be traced down to about 3 feet below the surface. Farther away from the Coombe Rock it is more or less stoneless and composed of a much disturbed mixture of sand and clay, and is about 8 feet in thickness. This deposit rests on a homogeneous, coarse, light-coloured sand, which is exposed only in parts of the cutting. The gravel of the Flood-plain terrace appears to be banked against a 3-foot cliff of this Coombe Deposit.

Half-a-mile west of this locality another section of Coombe Deposits can be seen in a cutting leading to a disused quarry belonging to the Thames Valley Portland Cement Company. Here the Coombe Rock is banked against a sloping cliff of chalk and appears to be a scree. It is about 20 feet thick and 24 yards broad. Its northern boundary lies at a natural slope, on which there rests a deposit of buff, sandy, almost stoneless, brickearth.

East of the road 500 yards east of Askew Farm, and 300 yards south of the South Essex Waterworks, a small patch of Coombe Rock was removed in October to uncover the Chalk for quarrying purposes. The thickness of it was only 4 to 5 feet; the rest of the Coombe Deposits is also very thin and probably does not extend to the south of the exposure.

In the low cliffs west of the village of East Tilbury, 8 to 10 feet of Coombe Deposits overlie the Chalk. Gravel is much mixed up with the chalk rubble and the deposit in places becomes a true gravel, possibly derived from the outlier of the 50-foot terrace gravel which lies to the north of the section.

2. Shropshire and Staffordshire District

T. C. Cantrill, B.Sc., District Geologist.
C. B. Wedd, B.A.
R. W. Pocock, B.Sc.
T. H. Whitehead, M.Sc., A.R.C.Sc.
T. Robertson, B.Sc.
} Geologists.

In Shropshire Mr. Wedd has begun the re-survey of the western end of the Shrewsbury coalfield and has advanced eastward from the neighbourhoods of Wollaston and Westbury in the Welshpool Sheet (151) towards Hanwood in the Shrewsbury Sheet (152). In the Wem Sheet (138) Mr. Pocock has mapped a large area east and south of Hodnet, and also a narrow belt of ground along the western margin of the Stafford Sheet (139). In the Shrewsbury Sheet (152) Mr. Cantrill has continued his examination of the valley of the Tern between Wellington and the county town.

In South Staffordshire Mr. Whitehead has surveyed an area extending eastward from Wombourn in the Dudley Sheet (167) to the neighbourhood of West Bromwich and Handsworth in the Birmingham Sheet (168), while an irregular tract in the southern portion of the latter Sheet has been mapped by Mr. Robertson in continuation of the work already done by Mr. Eastwood.

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PRE-CAMBRIAN

Of the ancient rocks of the Longmynd, upon which the Coal Measures rest to the south-west of Shrewsbury, nothing has been seen but a small tract of dolerite, intrusive in pink felsite, noted at Plealey by Mr. Wedd.

ORDOVICIAN

During his examination of the Bala rocks that bound the Shrewsbury coalfield at the north-eastern end of the Breidden Hills, Mr. Wedd had the advantage of the company of Prof. W. W. Watts, who has more or less completely correlated the Lower Bala sequence seen there with the corresponding series of Caradoc and Shelve. It appears that only the lower half (Caradocian) of the Bala is present, followed unconformably by strata of Upper Llandovery age, not exposed within the area mapped.

The lowest strata seen in the Bala succession, which consists essentially of shales, crop out in the bank of the Severn below Bausley Hill, where they contain pale ashes and a bed of black fine-grained grit. At a higher horizon the attenuated dolerite sill of Breidden Hill dies out eastward; and still higher the mass of fossiliferous ashes, which, with its included conglomerates of igneous material, continues the ridge of Middletown Hill, diminishes north-eastward in Bausley Hill, beyond which it appears to be cut off by one of a group of three faults that trend north-eastward. In the upper part of the sequence a small group of thin limestone-bands and thicker calcareous sandstone has been noted, in which the characteristic *Trinucleus* is *T. concentricus*, as determined by Mr. J. Pringle.

These Bala beds, with strong south-easterly dip, which locally becomes vertical or even inverted, crop out in the north-western limb of the great syncline of Long Mountain, of which the Ludlow and higher rocks occupy the trough. But the general north-eastward strike of the Bala rocks changes to east and even to south-east in the proximity of the faults above-mentioned.

SILURIAN

At the western end of the Shrewsbury coalfield, Mr. Wedd finds that the Tarannon and Wenlock Shales, like the Llandovery strata, are not exposed near Wollaston; but farther to the south-east the Wenlock beds are seen here and there in the south-eastern limb of the Long Mountain syncline, south-west of Westbury. They consist of shales and silty micaceous shales, in which at a high horizon calcareous nodules occur in several beds at Knolls Coppice. Graptolites are found at one or more levels; but these have not yet been determined, nor have the Wenlock beds been adequately searched for fossils.

The scanty exposures of the Ludlow rocks in the north-eastern end of Long Mountain suggest that the bulk of them consists of

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fine quartz silt, so well laminated as to have a shaly appearance. Fossils of characteristic Ludlow species have been found at several horizons; but in the highest beds re-surveyed, some distance below those assigned to the Old Red Sandstone on the published map (O.S. 60 N.E.), a silty sand-rock full of *Lingula cornea* J. de C. Sow. has been observed. This is indistinguishable in lithological character and fossil-contents from a bed assigned by Mr. T. H. Whitehead to the Downton Castle Sandstone in South Staffordshire, as Mr. Pringle noted on comparing specimens from the two localities. But the presence of Downtonian beds characterized by that *Lingula* below the Old Red Sandstone of Long Mountain had previously been recorded by Professors Lapworth and Watts.[1]

On the western side of the South Staffordshire coalfield the survey of the Silurian rocks of the Sedgley neighbourhood has been completed by Mr. Whitehead as far north as Ettingshall Park Farm.

North of Bilston Street, Sedgley, these rocks form a syncline pitching to the south, and well marked by the outcrop of the Aymestry Limestone. The Upper Ludlow beds (with *Chonetes striatella*, *Camarotoechia nucula*, *Goniophora cymbaeformis*, *Orthoceras bullatum*, etc.) in this syncline were well displayed in excavations made on a building-site just north of Bilston Street. These Upper Ludlow beds are overlain by coarse grits and sandstones of the Middle Coal Measures, which occupy the middle of the syncline. It is considered unlikely that Silurian strata higher than the Upper Ludlow can occur under these Coal Measures.

South of Bilston Street the synclinal axis is replaced by an anticlinal axis almost on the same alignment. It is believed, therefore, that a nearly east-and-west fault crosses the area. The anticlinal axis produces a broad outcrop of the Aymestry Limestone, which, in quarries north and south of Catholic Lane, may be seen dipping respectively at about 10° to the west, and at a low angle to the east. Farther south, at Modenhill, the easterly dip has increased to 20°. There is here, however, no trace, in the Aymestry Limestone, of the western limb of the anticline, and Upper Ludlow Shales (with *Chonetes striatella*, *Camarotoechia nucula*, etc.), dipping westwards, appear to abut directly against the easterly-dipping Aymestry Limestone. It is considered, therefore, that a short distance south of Catholic Lane, the anticlinal axis is replaced by a fault.

Another cross-fault, a little south of Cotwall End and Modenhill, throws down the 'Red Downtonian' (Ledbury Passage Beds) on the south against the Upper Ludlow beds to the north. The outcrop of these Red Downtonian beds extends southwards into Ellowes Park, and they are exposed in the stream-section

[1] 'The Geology of South Shropshire,' *Proc Geol. Assoc.*, vol. xiii (1893–4), 1894, pp. 328-9; 'Geology in the Field (Shropshire),' pt. iv., 1910, p. 760.

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referred to in the 'Summary of Progress' for 1920 (p. 12) and also in another stream 150 yards farther north. They have been described by Messrs. King and Lewis,[1] who considered that they form a complete anticline and dip both to the west and to the east under the Coal Measures (*op. cit.*, Fig. 2, p. 93). Observations made during the present survey, however, necessitate a modification of this view of the structure. On the east side of Ellowes Park there was found a small exposure of Upper Ludlow beds, dipping to the east. The Red Downtonian beds can be traced to within 20 yards or less of this exposure, in the stream-section along the northern boundary of Ellowes Park. About a quarter of a mile farther north, greenish sandstones, with a spine of *Onchus* (probably Downton Castle Sandstones), were found a little above the foot of the steep bank along which runs the drive to Ellowes Hall. It was ascertained by boring that the outcrop of the Red Downtonian beds extends to the foot of this bank. It seems clear therefore that a fault, throwing down to the west, must pass near the foot of the bank and along the east side of Ellowes Park.

West of the anticline in the Aymestry Limestone above referred to, the Upper Ludlow beds are overlain by Coal Measures sandstones, dipping to the west. Farther west a narrow strip of Silurian rocks is faulted in. The most northerly exposure in this strip occurs in a ditch about 100 yards north of Ladymore Road. Here nodular and flaggy limestones, and calcareous mudstones (with *Chonetes striatella*), dip at about 60° to the west. Similar Upper Ludlow beds are dug up in the burial-ground and in the fields farther south. At the southern end of this strip, at Cotwall End, Downton Castle Sandstones (identified by Messrs. King and Lewis[2]) overlie the Upper Ludlow beds.

East of the anticline in the Aymestry Limestone a shallow syncline brings in another outcrop of Aymestry Limestone, as evidenced by numerous fragments in the fields near Turlshill House. The continuity of this outcrop with that of Beacon Hill is probably somewhat broken by the cross-fault near Bilston Street.

The Wenlock Limestones and Shales are exposed at Hurst Hill in the form of a broken pericline, on the eastern side of which both bands of limestone crop out. West of the fault the upper band of limestone emerges south of Bilston Street; but north of that street the limestone does not appear on the surface on this side of the fault. It has, however, been mined underground between Beacon Hill and Cinder Hill. Some exposures of Lower Ludlow Shales in holes caused by subsidences yielded *Phacops vulgaris*, *Dalmanella elegantula*, *Bilobites biloba*, *Cyrtia exporrecta*, *Pleurotomaria lloydi*, etc.

[1] W. W. King and W. J. Lewis, 'The Downtonian of South Staffordshire,' *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xiv., pt. 2, 1917, p. 92.
[2] *Op. cit.*, p. 92.

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The fault that traverses the Hurst Hill pericline probably extends northwards to the neighbourhood of Sedgley Park. Southwards it has been followed to the main road from Sedgley to Tipton. Between this road and Hurst Hill Wood it throws down the Coal Measures on the east against the Silurian (Lower Ludlow) on the west.

The changes in the direction of apparent vertical throw shown by this fault are probably due to the fact that the more important component of the movement was horizontal rather than vertical. It is possible that the fault is a continuation of the one that similarly traverses the pericline of Mons Hill and the Wren's Nest.

CARBONIFEROUS : COAL MEASURES

It had long been surmised that the Middle Coal Measures were not represented in the Shrewsbury coalfield, where the occurrence of a Spirorbis limestone in the coal-bearing strata had been known for many years. Mr. Wedd's re-survey of the western part of the coalfield during the past season has proved that, at any rate as far eastward as Hanwood, Middle Coal Measures are entirely absent from its exposed area, and that only those higher groups are represented which have been classed in North Staffordshire and elsewhere as Upper Coal Measures.

The descending sequence in the western part of the Shrewsbury coalfield is as follows :—

	Denbighshire.	North Staffs.
Breccias : reddish-purple, calcareous, containing a large proportion of Carboniferous Limestone material; sandstones, reddish-purple, more or less pebbly (Alberbury Breccia)		
Sandstones : red, purple, and lavender, some of the more massive in the upper part being pebbly; purple shales; occasional thin bands of quartz conglomerate - - - - - - -	Erbistock Beds.	Keele Beds.
Shales : chiefly light-grey, but with subordinate red shales and purple mottled clays; pale-grey or white sandstones; in the lower part two or three coals, and at least two bands of Spirorbis limestone, one being at the base. Thickness 400 feet or rather more - - - - - - -	Coed-yr-allt Beds.	Newcastle Beds.
Clays and marls : purple and mottled, with at least four bands of purple limestone, the highest only 2 feet below the Spirorbis limestone at the base of the overlying Newcastle Beds; the lowest 5 feet or 6 feet rubbly and calcareous (resting unconformably on purple-stained Bala beds in Braggington Brook). Thickness represented, about 20 feet - - - - -	Ruabon Marls.	Etruria Marls.

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The whole sequence is here assigned to the Upper Coal Measures in accordance with the classification adopted on recent maps of the Geological Survey for the North Staffordshire and other Midland coalfields. Dr. Kidston, however, on palæobotanical grounds, regards only the Keele Series ('Permian' of the old maps), with possibly higher Carboniferous beds such as the Alberbury Breccia, as belonging to the Upper Coal Measures of the Continent; and relegates the two lower divisions to a Staffordian or Transition Series intermediate between Middle and Upper Coal Measures.

Only the topmost beds of the lowest division (Etruria or Ruabon Marls) are present at the outcrop in the western part of the Hanwood coal-district, and these have been detected at only two localities, viz., in Braggington Brook and in a stream west of Westbury. But the similarity both in lithological character and in colour of the remaining sequence (exclusive of the Alberbury Breccia at the top), and the identity of certain details, establish a correlation with the corresponding divisions of the Upper Coal Measures in Denbighshire and North Staffordshire. The more important details of resemblance are the presence of thin limestone-bands in the highest beds of the lower red division (Etruria Marls), and of two at its junction with the overlying pale-grey beds, the upper of these two usually containing *Spirorbis* or entomostraca; the recurrence of more thin limestones, including a second Spirorbis band, in the middle division (Newcastle Beds); and the incoming of lavender-coloured felspathic sandstones in the lower part of the upper red division (Keele Beds). Moreover, Dr. Kidston's examination of plants collected by Messrs. Templeman and Hester, chiefly from the lower beds of the middle division, indicates a zonal position higher than the Middle Coal Measures.

Of the above sequence the middle division (Newcastle or Coed-yr-allt Beds) alone contains workable coal-seams, and constitutes the Hanwood coal-district, in which the prevalent pale colour of the measures contrasts with the generally dark colour of Middle Coal Measures shales. It contains in its western half only two or three coals, and these rarely attain an individual thickness of more than two feet, only one of them being as a rule thick enough to work. Coal is now raised in that part of the field in the neighbourhood of Hanwood alone; but in former times it has been worked at several localities westward as far as the extremity of the exposed field, viz., in the districts of Pontesford, Asterley and Westbury, and at Bretchel, Wollaston, Braggington and Coedway.

Besides the transfer of red beds formerly classed as Permian to the Upper Coal Measures, the re-survey has necessitated certain other changes of mapping. At the north-western extremity the outcrops of the several divisions of the Upper Coal Measures do not sweep round in a uniform synclinal curve as represented on the extant map (60 N.E.). The junction of the

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Coed-yr-allt or Newcastle Beds with the Bala is there undoubtedly faulted by one of the north-easterly faults mentioned above, though in Braggington Brook intensely stained Bala beds are exposed on the downthrow side of the fault under the thin remnant of the Ruabon Marls; the upper red division also extends there farther westward than the 'Permian' outcrop as shown on the old map, and is faulted against the Newcastle Beds by another fault of the same group; also there is reason to believe that a southward-trending dislocation on the western side of Alberbury Park cuts out an appreciable part of the Keele Beds below the Alberbury Breccia, the highest member of the Upper Coal Measures sequence of the district.

So far as the work has proceeded, no indication of unconformability has been detected within that sequence.

Around Ollerton, between Wellington and Market Drayton, certain purple marls with thin greyish sandstone bands, shown on the old map (73 S.E.) as Permian, are now referred by Mr. Pocock either to the Keele Beds or to the Etruria Marls. They have a slight dip to the north-west, in which direction they appear to pass beneath the Lower Mottled Sandstone of the Bunter. On the south they are bounded by a fault that passes between Ollerton and Child's Ercall.

The re-survey of the South Staffordshire coalfield has been continued by Mr. Whitehead between the Western Boundary Fault, near Sedgley, and the neighbourhood of Wednesbury and West Bromwich. Mr. Robertson has also mapped a small area between Wolverhampton and Bilston.

A small area of Middle Coal Measures crops out west of Sedgley, near Sedgley Hall and Cotwall End. There are here traces of old open workings in which the Thick Coal is said to have been got. Coal has also been worked underground near Sedgley Hall. This outcrop of Middle Coal Measures is bounded on the west by the Western Boundary Fault, and is probably also faulted on the east against the strip of Silurian rocks mentioned on p. 27.

The Red Downtonian rocks in and near Ellowes Park are, on the west, overlain unconformably by Middle Coal Measures containing two coal-seams. This outcrop is bounded on the west by the Western Boundary Fault. Other areas of Middle Coal Measures near Sedgley have already been alluded to in discussing the Silurian rocks.

At Upper Gornal thick and massive sandstones form a conspicuous element in the lower part of the Middle Coal Measures. These include the well-known Gornal Sandstone, which is quarried to some extent for building-stone, and also as a source of silica sand.[1] These sandstone beds, somewhat diminished in thickness, extend northwards to the Sedgley-Tipton road. To the south-east and south-west of Gornal they diminish rapidly in thickness.

[1] 'Special Reports on Mineral Resources, vol. vi., Refractory Materials' (*Mem. Geol. Surv.*), ed. 2, 1920, pp. 13, 98, 99.

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At three localities, namely, near Parkes Hall (Woodsetton), near The Coppice (Hurst Hill), and about 700 yards north-west of Cinder Hill, there have been found evidences of coarse conglomeratic beds at or near the base of the Middle Coal Measures. At these localities there occur abundant and large pebbles of quartzitic grit, together with fragments of conglomerate and of coarse grit with a ferruginous cement. The presence of such coarse material at these places is of interest in connection with the view put forward by Mr. W. King[1] as to the probable derivation of the materials forming the basal Middle Coal Measures conglomerates from the neighbourhood of the Lickey Hills. Mr. King remarks that at Ellowes Park these basal conglomerates have become one band of coarse sandstone. At the localities mentioned above, however, at equal or greater distances from the Lickey, coarse basal conglomerates still remain. A tentative explanation may be offered which might reconcile this fact with Mr. King's views of the source and distribution of the coarse sediments. It is conceivable that in early Middle Coal Measures times the Sedgley-Rowley-Lickey uplift may have existed as a shoal or bank but little below, or even above, sea-level. Along such a bank coarse shingle might be drifted by tidal or current action to distances farther from its source than in the deeper water on either side.

East of Sedgley the ground is largely covered by buildings and debris, so that little evidence regarding the Coal Measures can be obtained from surface observations. The outcrops of several of the coal-seams can, however, be traced at intervals along the border of the Silurian ground. Near the outcrops the coals are being got in slopes and shallow pits, and the clays associated with the Bottom Coal are being dug in open workings. Away from the crop, mining has almost ceased, owing to flooding. Some trouble has been experienced in the workings near the crop from 'black damp,' which has probably been driven up to this level by the rise of water in the deeper workings.

During the coal strike several seams, including the New Mine and Stinking Coals, were worked at the outcrop south of St. Chad's Church, West Coseley. The measures here have a westerly or north-westerly dip. Considering this in conjunction with the north-easterly dip of the measures off Mons Hill, and of the easterly dip near The Coppice, Hurst Hill, it is clear that the measures lie in the form of an almost complete basin. The central portion of this basin is obscured by material thrown in to restore the level of the ground after the removal of the Thick Coal; but, so far as can be ascertained, the highest beds present consist of the clays of the Ten Foot Measures, which here contain abundant plant-remains.

The Etruria (Old Hill) Marls certainly extend as far west as Horseley Heath, and possibly as far as the canal near Tipton Station. They are probably brought into this position by a

[1] 'The Plexography of South Staffordshire in Avonian Time.' *Trans. Inst. Min. Eng.*, vol. lxi., pt. 5, 1921, p. 164.

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fault, having a downthrow of from 60 to 90 ft. to the south, which runs through Horseley Colliery in a W.S.W.–E.N.E. direction.

At Tibbington beds that seem to be transitional from the Middle (Grey) Coal Measures to the Etruria Marls are seen in a large clay-hole at the brickworks. The clays are mostly of a bluish-grey colour, and are of Middle Coal Measures rather than of Etruria Marl type, though a reddish colour sets in near the top. About half-way up the section there is a coal-seam about 2 ft. thick, which is locally identified as the Two Foot Coal. Another coal about 9 in. thick occurs about 20 ft. higher. At the bottom of the hole, some 40 ft. below the Two Foot Coal, there is a massive gritty sandstone of distinctively 'espley' type. Similar apparently transitional beds were seen at Ocker Hill.

On the western side of the coalfield the outcrop of the Keele Beds near The Straits extends northwards nearly to Cotwall End. They are poorly exposed in The Dingle (600–700 yds. south of Cotwall End), where they lie close against the Western Boundary Fault. It is probable that another outcrop of Keele Beds exists in the neighbourhood of the coal-shaft near Sedgley Hall, faulted on the west against the Enville Beds and on the east against the Middle Coal Measures. The presence at the surface of Keele Beds here is inferred from the section of the shaft,[1] which shows about 120 ft. of red marl with three bands, 2 to 3 ft. thick, of sandstone, followed, downwards, by Middle Coal Measures. So great a thickness of marls, relatively to the sandstones, is more characteristic of the Keele Beds than of the lower portion of the Enville Beds.

On the eastern side of the coalfield Keele Beds probably outcrop over the whole of the area around West Bromwich between the Eastern Boundary Fault and Sandwell Park. Much of this area is drift-covered, but the red and mottled marls, with lenticular sandstones up to 40 ft. thick, of the Keele Beds are exposed in the cutting of the Great Western Railway near West Bromwich Station.

This outcrop of Keele Beds extends northwards to beyond Newton Road, where it is probably terminated by the Eastern Boundary Fault, which is believed to change its direction near Carter's Green and to run from here north-eastward towards Hill Farm near Great Barr.

Enville Beds.—On the western side of the South Staffordshire coalfield the Enville Beds[2] are well developed west of Sedgley, around Gospel End and Sandyfields. Near the latter place the Calcareous Conglomerate Group forms a conspicuous scarp slope facing south-east. Upon this, subsidiary ribs, due to the

[1] 'The South Staffordshire Coal-Field' (*Mem. Geol. Surv.*), ed. 2, 1859, p. 182, and Vert. Sect., Sheet 17, No. 21. Another version of the section, the upper part of which agrees with that quoted by Jukes, has been supplied by Mr. W. King.

[2] *See* Appendix VII, p. 169.

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calcareous bands, are well marked, and are usually three in number; though they may be reduced to two or increased to four by the disappearance, or splitting, of one or other of them. Near Sedgley Hall the highest calcareous band, consisting of pebbly calcareous sandstone and conglomerate, dipping north-west at 40°, is succeeded upwards by beds, probably 100 ft. thick or more, composed largely of breccias. These breccias are coarser than any others seen in this neighbourhood, though finer than those near Wordsley and Kingswinford, and much finer than those of the Clent Hills, which they, in other respects, resemble. The stream-sections show that these breccias are followed upwards by a series of bright-red marls and marly sandstones, with 'fish-eyes,' and some beds of green sandstone.

The three calcareous bands, more or less well defined, of the Calcareous Conglomerate Group can be traced over the whole area between Penn Common and Himley Park. They are repeated in places by faults, and the highest band is followed, as near Sedgley Hall, by the Breccia Group, with breccia or breccia-sandstone in the lower portion. Fine-grained breccias can be traced along Penn Brook (south of Penn Common), their continuity interrupted by faults, from near Lloyd House to within half a mile of Hickmerelands Farm. The ground about Penn Common is largely covered by superficial deposits; but the deeper stream-courses to the west and east expose the bright-red marls with sandstones that overlie the beds with breccias. At Alder Coppice, east of Penn Common, a thin fine-grained breccia occurs amongst these marls. Near the Colton Hills these red marls have been worked for brick-making, and an excavation has been made in them immediately at the foot of the Bunter Pebble Bed escarpment.

On the eastern side of the coalfield the Enville Beds occur in Sandwell Park. Here, in an old quarry and in the trenches of some old rifle-butts, there are exposed pink calcareous sandstones, and calcareous conglomerate or breccia. This last contains small subangular pebbles of red and yellow chert. These beds, which have an easterly dip, are considered to lie at the base of the Enville Beds, as no trace of similar rocks can be found farther west. They can be traced northwards to Sandwell Hall, near which they are believed to come against the outcrop of an important fault proved underground in the workings of Sandwell Park Colliery. This fault, which throws down to the east, has the effect of shifting the outcrop of the base of the Enville Beds about a mile northwards, to the neighbourhood of Newton Road Station, near which they were recorded by Mr. Cunnington.[1]

South of Sandwell Park the ground is drift-covered; but the Enville Beds are again exposed in the cutting of the Great Western Railway west of Handsworth and Smethwick Station.

[1] 'Summary of Progress' for 1912 (*Mem. Geol. Surv.*), 1913, pp. 28–9.

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They here include the coarse calcareous conglomerate mentioned by Jukes.[1]

PERMIAN

In the Lichfield Memoir certain breccias that underlie the ordinary conglomerates and pebbly sandstones of the Bunter Pebble Beds and rest usually upon the Enville Beds were described under the name 'Hopwas Breccia,' and assigned with doubt to the Permian system.[2] On the south-eastern side of the South Staffordshire coalfield, near Handsworth, evidence of similar breccias has been found at three places by Mr. Whitehead. Near Manwoods Farm certain of the fields are strewn with angular fragments of grey quartzite, and an overgrown quarry shows traces of red marl and sandstone with some angular fragments. These fragments resemble those described[3] as occurring in the Hopwas Breccia near Sutton Coldfield. In some allotments north of Handsworth Cemetery shallow excavations expose red marls and marly sandstones with thin beds of fine-grained breccia, of which the constituents appear to be chiefly fragments of decomposed and red-stained igneous rock. Similar beds are to be seen in small excavations about a quarter of a mile east of The Austins, on the eastern side of the Sandwell Road. These fine breccias and red marls resemble some beds which, in the canal-cutting near Hamstead, lie unconformably on the Enville Beds, and are believed to represent the Hopwas Breccia.

TRIAS

Of the Triassic strata that abut against the Alberbury Breccia in the western part of the Shrewsbury coalfield little has yet been seen. Mr. Wedd finds that they occupy the low ground that descends to the Severn valley below the dip slope of that breccia, and are not well exposed. They belong to the Bunter division, but their classification in detail and the nature of the boundary between them and the breccia at Alberbury are not yet certain.

Mr. Pocock finds that, south and east of Hodnet, the Lower Mottled Sandstone occupies much of the surface. It is bounded on the west by a fault that brings in the Keuper Marl and Upper Mottled Sandstone of the Hawkstone area.

The Bunter Pebble Beds form a small outlier at Hodnet, bounded on the west by the same fault. They form the higher ground north of Wistanswick, and crop out also around Child's Ercall, Great Bolas, and Shray Hill. Their base is markedly

[1] 'The South Staffordshire Coal-Field' (*Mem. Geol. Surv.*), ed. 2, 1859, p. 11. *See also* W. W. King, 'The Permian Conglomerates of the Lower Severn Basin,' *Quart. Journ. Geol. Soc.*, vol. lv., 1899, p. 116, and W. H. Hardaker, 'On the Discovery of a Fossil-bearing Horizon in the "Permian" Rocks of Hamstead Quarries, near Birmingham,' *ibid.*, vol. lxviii., 1912, pp. 652 and 654.

[2] 'The Geology of the Country around Lichfield' (*Mem. Geol. Surv.*), 1919, chap. vi.

[3] *Op. cit.*, p. 123.

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calcareous in places, as in the left bank of the Tern at Great Bolas. At Hungryhatton many silicified logs of wood were found in a small exposure of what appear to be Pebble Beds, and fragments of this silicified wood are common on the surface of the fields in the vicinity; but as the fossilised wood appears to be a Carboniferous species, the beds in question may prove to be some part of the Coal Measures.

The Upper Mottled Sandstone is well exposed in the steep slopes of the Marchamley and Kenstone Hills and in Hodnet Park. At Marchamley Hill it is separated from the Waterstones by about 20 ft. of white fine-grained Lower Keuper Sandstone, which appears to be absent at Kenstone Hill. This white sandstone thickens westwards and is well developed in the Grotto Hill at the western end of Hawkstone Park. From this point its outcrop is shifted nearly four miles to the south-west by the western boundary fault of the Hawkstone area, and where it appears on the west of the fault it forms the well-known building-stone of Grinshill.

The Waterstones attain a greater thickness near Marchamley than at Grinshill. A total of 32 ft. can be seen in the road-cutting at Marchamley Hill.

The Keuper Marl, of the usual red and grey shaly type, is faulted, north of Marchamley, against the Waterstones and Keuper Basement Beds of Hawkstone Park, and occupies a considerable area to the north. It can be seen also east of the Tern, near Stoke Grange, dipping steeply westward, away from the eastern boundary fault of the Hawkstone area.

The area surveyed by Mr. Robertson in the southern environs of Birmingham (Sheet 168) is roughly triangular in outline, comprising the ground extending from the Birmingham Fault eastwards as far as the valley of the Cole, and extending southwards from Aston Manor to about two miles south of King's Norton. The Birmingham Fault runs in a south-west direction from Saltley to Northfield, with downthrow to the south-east. Along this part of its course, except in the extreme south, it appears generally to bring Keuper Marl into contact with Lower Keuper Sandstone at the surface. Within half a mile of the fault the Lower Keuper Sandstone usually gives place to Upper Mottled Sandstone, since the prevailing dip is south-east. On the downthrow side of the fault the dip is also south-east, at a low angle, as shown by exposures at King's Norton, Northfield and King's Heath. The throw of the fault appears to reach its maximum in the neighbourhood of Selly Oak or slightly farther to the north. A boring at Selly Oak Baths passed through more than 400 ft. of Keuper Marl. Farther north, at Saltley, the throw is less, and the sandstone was reached at a depth of about 80 ft. in a boring at the Corporation Gasworks in Duddeston Mill Road. A mile south-west of Northfield, where the fault is cut off by a smaller N.N.W.–S.S.E. fault, the throw has decreased so much that Keuper Sandstone crops out on both sides.

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South-eastwards from the fault the thickness of the Marl gradually increases, and is at least 600 ft. where bored through at King's Heath. Thence it stretches to the east under the Cole valley, and is continuous towards Solihull with that underlying the Forest of Arden.

On the eastern side of the South Staffordshire coalfield Mr. Whitehead finds that the Bunter Pebble Beds constitute the highest solid formation over the greater part of the Handsworth area, though they are almost everywhere covered by drift. Their base is, however, well seen at Hamstead Hill, where they rest directly upon the Enville Beds. About 300 yards west of Handsworth and Smethwick Station, in the railway-cutting, the base of the Pebble Beds is again exposed, resting, as at Hamstead Hill, directly on the Enville Beds.

Owing to the prevalence of drift, the position of the boundary between the outcrop of the Upper Mottled Sandstone and that of the Bunter Pebble Beds, south of Handsworth, can only be conjectured. The former division is, however, exposed under the drift in a sandpit at a salvage depôt of the Birmingham Corporation (formerly the Handsworth U.D.C. Sanitary Depôt) about 600 yards east of Handsworth and Smethwick Station. This place is very much further west than the Upper Mottled Sandstone is represented as extending on the Old Series one-inch geological map (62 S.W.). This evidence corresponds with that found by Mr. Eastwood[1] farther south. It is probable that the fault mapped by him, east of the cemetery, Smethwick, to account for the narrowing of the Pebble Bed outcrop, extends northwards to beyond Handsworth and Smethwick Station.

On the west of the South Staffordshire coalfield the Bunter Pebble Beds crop out from Earlswood southwards to Himley Hall, dipping to the east, and faulted on the east against the Enville Beds. Here they are well consolidated, and consist of massive pebbly sandstones and quartzose conglomerates, in places with a calcareous cement. Small lenticles of calcareous breccia occur in the basal portion. About Upper Penn, on the other hand, the Pebble Beds consist of semi-consolidated pebbly and sandy beds. Here the Bunter Pebble Beds rest directly upon the higher red marls of the Enville Beds.

East of Wombourn the Bunter Pebble Beds are underlain by the Lower Mottled Sandstone, which is well exposed in the stream-course called Rushford Slang, in the grounds of the Wodehouse.

The Upper Mottled Sandstone crops out over the whole area around Wombourn and as far north as Orton, except where it is capped by Keuper. The Basement Beds of the latter occupy the high ground east and south-east of Orton. They consist of reddish-brown pebbly sandstones with lenticles of calcareous breccia. Similar pebbly sandstones were found capping some high ground south-west of Wombourn and just west of the Stour-

[1] 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, pp. 18, 19.

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bridge–Wolverhampton road. The discovery here of an outlier of the Keuper Basement Beds is of interest, as it approximately fixes the position of the southerly continuation of a fault, which, near the Lloyd House, throws the Upper Mottled Sandstone and Keuper Basement Beds against the Bunter Pebble Beds.

GLACIAL AND POST-GLACIAL

At the western end of the Shrewsbury coalfield Mr. Wedd has examined some ground drained by the Rea Brook and a nameless confluent, which, rising in Hargreaves Wood, flows eastward by Westbury and Stretton Heath. At Hanwood the pre-Glacial valley of these united streams is constricted by a tough red till composed largely of local material derived from the outcrop of the Erbistock Beds, and there constituting the lowest member of the drift. This constriction of the valley has had a marked effect in holding up the drainage during the melting of the ice-sheet.

The till and higher drifts of looser texture are sufficiently thick to have obliterated the physiographical features of solid rock north of the valley at Hanwood, but are less thick on the rising ground south of it. Farther west also, on the northern side of the valley, the drift diminishes in thickness. On Wattlesborough Heath, in a new well on the northern side of the Shrewsbury road, 22 ft. of tough purple till of similar origin was found to become gravelly in its lower part. This was probably not far above the solid rock; for immediately north of the Heath the rising ground made by sandstones of the Erbistock Beds is bare of Glacial debris. Still farther west the superficial drifts of loose and often rough gravelly material, while completely covering the surface of the Coal Measures (Newcastle Beds) between Halfway House and Wollaston, are not thick enough to obscure the escarpments of sandstones, so that it is possible to trace the outcrops of unseen beds in spite of the drift covering.

Torrential conditions at the close of the Ice Age are exemplified by coarse rudely-bedded gravels derived largely from the Lower Palæozoic rocks of the Long Mountain. In the valley of the stream above-mentioned as a confluent of the Rea Brook, this material was swept off the steep slopes of Ludlow rock and out of rapidly-eroded gorges to form thick gravel-bars, which impeded the drainage and account for the devious course of the present stream for some distance below its source in Hargreaves Wood. The obstruction of the valley lower down at Hanwood caused the formation of small lakes, and in one of these, between Wattlesborough Heath and Halfway House, laminated clays were deposited on a gravel base some 10 ft. or 15 ft. above the present stream. These clays have long been worked for brick-making.

In the southern bank of the Severn below Belan Bank, north of Middletown, Professor Watts and Mr. Wedd have noted glacial striæ on a *moutonnée* surface of dolerite. The striæ indicate a local direction of ice-flow due eastward.

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In the area surveyed by Mr. Pocock much of the ground is free from drift. Boulder-clay of a sandy type occurs south of Hodnet and near Peplow, but is nowhere very thick. The same type of drift is found near Child's Ercall and Eaton upon Tern, as also in the neighbourhood of Great Bolas and Cherrington. Sands, possibly of glacial origin, are seen east of Stoke upon Tern and at Hodnet Heath.

Terraces of sand and gravel occur along the course of the River Tern at varying heights above the alluvium of the river.

In the area to the south of Birmingham Mr. Robertson finds that the drift is, as a general rule, confined to the higher ground. Along the valleys of the Rea and Cole the Keuper Marl is exposed above the alluvium in most places, but is capped by a variable thickness of glacial material, in places clayey, but elsewhere sandy or gravelly.

Around Selly Oak the drift can be roughly divided into a lower group of clays and an upper group of more sandy and gravelly material, as shown by Mr. Eastwood[1] in the California area about a mile and a half farther west.

The Bournville and Cotteridge area is noteworthy for many large erratics. Some of these are preserved on the Cadbury estate at Bournville, and others in Cotteridge Park. Most of them are of Arenig volcanic type, but a few are quartz or sandstone. One Arenig boulder found just west of Bournville Station measures 8 ft. by 7½ ft. by 5 ft., and weighs 9 tons. Similar boulders up to 5 ft. in length are to be found on the south side of the Lifford-Northfield ridge, lying in some cases in the drift and in others on the Keuper Marl slope below it. South of this ridge, as far as West Hill, the country shows rounded marl features free from drift, and no large erratics were seen.

The drift on the high ground between the valleys of the Rea and the Cole can be divided into two parts. South of King's Heath it is mainly clayey in character; but north of this, by Moseley and Sparkhill to Bordesley, it is in the main gravelly and sandy. A tongue of sand and gravel also extends up the left bank of the Cole as far as Trueman's Heath (south-west of Shirley), and may be continuous with the Moseley gravel. The junction between the gravelly and the clayey drift appears to be very indefinite; the gravels and sands, however, come down to lower levels than the clays. They are over 100 ft. thick at Moseley, whereas the clayey drift south of King's Heath rarely attains a thickness of more than 20 ft.

The majority of the pebbles composing the gravels are of quartzite, with smaller numbers of vein-quartz, grit, chert, and conglomerate. Igneous pebbles also are frequent, including some of granite, of quartz-porphyry, and of Rowley basalt. Most of the pebbles are probably of local origin, and can be traced to the Triassic and Carboniferous rocks exposed farther to the west. The far-travelled ones can in the majority of cases be matched

[1] 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, p. 22.

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in North Wales, whilst no characteristically Scottish or Lake District erratics occur. The gravel along the left bank of the Cole valley near Yardley Wood appears much richer in grit and conglomerate pebbles than that at Moseley.

In the area around Handsworth mapped by Mr. Whitehead the drift is mostly gravelly in character, but with some admixture of clay and loam.

In the valley of the Tame, west of Perry Barr, the fields a little above the level of the alluvium are abundantly strewn with pebbles. Of these the most common are of quartzite, of Bunter type; but many fragments occur of calcareous sandstone and chert conglomerate of Enville Bed type, and of quartzose conglomerate with a ferruginous cement. These materials probably represent a deposit that should be classed with the late-Glacial gravels found farther north.[1]

At the Birmingham Corporation Salvage Depôt (p. 35), near Handsworth and Smethwick Station, a sand-pit shows about 12 ft. of rudely false-bedded pink and brown sand, with lenticles of gravel and clay, resting on some 15 ft. of pink quartzose sand with rare pebbles. At Park Farm near Handsworth Golf Course another sand-pit exposes about 16 ft. of pebbly sand, loam, and gravel, of which the lower portion shows fairly regular bedding. In a ditch a little to the east of this, and at a lower level, there was found a stiff purple mottled clay with a few pebbles. Red and greenish mottled clays, mingled with sand and pebbles, were also seen in this neighbourhood.

The higher ground of Sandwell Park and Handsworth Cemetery is occupied by sandy and gravelly drift with false and disturbed bedding. Fragments of ferruginous conglomerate, like that seen near Perry Barr, were found in the gravel-pits in Sandwell Park. A bed of this conglomerate was seen *in situ*, interbedded amongst the drift deposits, in the canal-cutting east of Spon Lane.

The valley between Sandwell Park and West Bromwich is free from drift, as is also a small area of the highest ground in the centre of West Bromwich itself. From here the drift extends northwards to the Tame valley near Hill Top, varying in thickness, and consisting chiefly of gravelly materials, but with beds of loam and clay in places. A distinction between bedded and unbedded drift can sometimes be made in the sections, but their similarity in composition renders their separation, away from the immediate neighbourhood of the sections, extremely difficult.

Outlying patches of gravelly or pebbly drift occur at New Town, also between Horseley Heath and Toll End, and again at Ocker Hill. West of these places the ground is free from drift.

West of the South Staffordshire coalfield the drift, in the area surveyed, is confined to three patches of unbedded gravel, with a matrix of red or orange sand, lying at a height of from 310 to 340 ft. above Ordnance Datum, near Wombourn.

[1] 'Geology of the Country around Lichfield' (*Mem. Geol. Surv.*), 1919, p. 190.

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About Penn Common and the neighbouring fields the solid geology is largely obscured by a deposit consisting of red clayey material, mingled with many Bunter pebbles, and with some derived from the Glacial drift. The deposit has very indefinite boundaries, and is believed to be of the nature of talus, rather than boulder-clay in place.

Several erratic boulders of granite and other igneous rocks may be seen in Upper Penn village. One of pink granite lies on Penn Common, and another, of granite or of syenite, was seen near Wombourn. The incised character of the stream-courses about Penn Common and Wombourn is a feature of interest.

3. Lancashire District

Headquarters: Manchester.

W. B. Wright, B.A., District Geologist.
R. L. Sherlock, D.Sc., A.R.C.Sc.
D. A. Wray, M.Sc.
W. Lloyd, B.Sc.
L. H. Tonks, M.Sc.
} Geologists.

This unit began its field season in the spring and commenced the re-survey of the Rochdale Sheet (76). Much time was required for the establishment of the new office in Manchester and for getting into touch with the mining and other interests in the district; discussion of the results of this year's field work may therefore be advantageously postponed until the relations of the formations in different parts of the area have been more completely studied.

The district between Ramsbottom and Turton, surveyed by Mr. Wright, is composed partly of Lower Coal Measures and partly of the higher members of the Millstone Grit. Much of the ground is highly faulted, and it is difficult to find sections to establish an undoubted succession. Around Holcombe Hill, however, the strata are undisturbed, and sections are available showing the local sequences from the Rough Rock to the uppermost member of the Third Grit series. The Sand-rock Coal within the Rough Rock is exposed in the quarries along the escarpment above Holcombe. It is about 12 inches thick with a sandstone roof and is underlain by two feet of fireclay resting on the lower division of the Grit. This coal has been traced in the neighbourhood of Turton.

At Holcombe the Haslingden Flags are poorly developed; they rest on grey mudstones, about 100 feet thick, which pass downwards into dark shales with a marine band at the base, overlying a coal about 13 inches thick, the Upper Holcombe Seam. This is well exposed to the north of Redisher Bleach Works and on the opposite side of the valley; it has a fireclay seat about 3½ feet thick which passes down into strong sandy shales with sandstone ribs visible for a thickness of about 15 feet. Below this the section is obscured, but 30 or 40 feet below the

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Upper Holcombe Seam a second seam is poorly exposed in the brook below. It rests on about 4 feet of sandy fireclay with ferruginous concretions, beneath which comes the uppermost bed of the Third Grit.

Binney[1] in his description of this section, which he makes the type section of his 'Holcombe Series,' mentions a third coal seam, 8 inches thick, the 'Middle Coal,' and places it some six feet below the top coal. This seam is not at present exposed in the sections described above, but information from a boring in another locality suggests that it may possibly exist, though it certainly does not lie as near the Upper Holcombe Seam as Binney suggests.

At Edgworth, about two miles west of Holcombe, the Haslingden Flags attain a fine development and have been very extensively quarried.

Dr. Sherlock has commenced mapping around Todmorden and Accrington. Accrington is situated in a synclinal hollow extending in a W.S.W.–E.N.E. direction. About two miles to the south of the town the Lower Coal Measures give place to the Millstone Grit, but the actual junction is often a fault. However, on Haslingden Moor the Coal Measures seem to rest normally on Millstone Grit, although the two are obscured by peat.

At Accrington the Lower Mountain Mine has been, and is still being worked, as well as, to a small extent, the Upper Mountain Mine. About a mile and a half to the east of Accrington, the Middle Coal Measures, with the Arley Mine at the base, crop out on a high moor, and during the recent strike the seam was extensively worked at outcrop. The Middle Coal Measures occupy only a narrow space between a pair of faults.

The Millstone Grit comes to the surface midway between Accrington and Haslingden. In the small area surveyed, round the latter town, the 1st or 2nd Grits and some sandstones below the 2nd Grit crop out, the 3rd Grit not being reached. The 1st Grit, or Rough Rock, has the character of the 4th (Kinderscout) Grit and is a coarse grit with small pebbles of quartz. The Sandrock, or Feather-edge Coal, that divides the Rough Rock, has no commercial value. At Haslingden it is a pockety coal about 18 inches to 2 feet in thickness, interstratified with clay and resting on 18 inches to 3 feet of clay with ironstone. The outcrop of this coal often makes a small surface feature. About 150 feet of strata separate the 1st and 2nd Grits.

The 2nd Grit, locally known as the Haslingden Flags, is worked for setts and flags, and was at one time also used for 'slates.' Enormous quarries near Haslingden prove the former extent of the industry. The rock is a sandstone, not a grit. A faint greenish tint characterises the Haslingden Flags, and the same colour is noticed in the mudstones below. These have often a spheroidal structure. The thick masses of flag are not on a

[1] 'The Lancashire and Cheshire Coal-Field,' *Trans. Geol. Soc., Manchester*, vol. i., 1860, p. 79.

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constant horizon, and pass laterally into shale or mudstone. At Haslingden the sandstone is about 100 feet in thickness.

The physiographic features of the district are of interest. The ground is heavily burdened with Glacial Drift. Accrington itself stands for the most part on boulder-clay, and Haslingden on sand and gravel. Channels cut by waters from the melted ice are seen at various elevations. One channel has been utilised by the high road from Rising Bridge, Baxenden, to the north end of Haslingden. This channel has a floor of peat and is bordered on the west by a large whalebacked ridge of drift.

The present streams flow in deep hollows, or cloughs, and, up stream, in practically every case a small waterfall is reached. Above the falls the valleys are much less deeply trenched than below. It is evident that there has been rejuvenescence of the streams since the Glacial epoch.

Mr. Wray was occupied in the moorlands east and south of Rochdale and Littleborough. Here again the Sand-rock or Feather-edge Coal occurs in the upper part of the Rough Rock; it is well exposed in two quarries at Ogden Edge, where it is about 2 feet thick and under- and overlain by grit.

The Lower Coal Measures attain a thickness of over 1,300 feet in this district, the upper limit being taken at the Arley or Royley Mine Coal, the lowest thick coal of the Middle Coal Measures. They consist of an alternation of shales and sandstones, with several thin coal seams. The beds have a general easterly and south-easterly dip, and are traversed by numerous faults, which for the most part range in a north-westerly direction. The several coals known locally as 'Mines' in ascending order are as follows: the Six-inch Mine; Yard Mine; Lower Foot Mine; Mountain Mine or Ganister Coal; Bullion or Upper Foot Mine; Inch Mine (with an important bed of fireclay underlying it which is being worked in the neighbourhood of Littleborough); and the Forty Yards or Upper Mountain Mine. Along the southerly part of the district the more important Mines have been worked in collieries of considerable depth, but in the north around Littleborough they crop out along the flanks of the moorlands and have been extensively wrought in shallow workings. Except in the neighbourhood of Rochdale, where the Mines occur at a considerable depth, the coals have been largely worked out.

The Six-inch Mine occurs within a few feet of the Rough Rock. It was formerly worked along its outcrop at Binns, near Higher Ogden, where its roof consisting of black shale is crowded with impressions of *Aviculopecten, Goniatites*, &c. This is overlain by sandy shales and flagstones, above which comes a massive sandstone, to which Binney[1] applied the name of 'Woodhead Hill Rock.' This sandstone, 60 to 80 feet above the base of the Lower Coal Measures, is well developed on Shore Moor, to the north of Littleborough, on Whittaker Moor, and

[1] *Trans. Geol. Soc., Manchester*, vol. i., 1860, p. 75.

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on high ground on both sides of the Piethorne valley at Higher Ogden. In places it closely resembles Millstone Grit.

The Yard Mine Coal occurs a short distance above it in these localities, and in this position may be well seen at the foot of Tunshill and Helpet Edge. It ranges from 2 to 3 feet in thickness, but is an impure coal with many shaly partings and has not been extensively worked.

A continuous section between this coal and the Forty Yards Mine Coal is well exposed along the eastern slopes of Tunshill and Helpet Edge and in the intervening country where the several coals have been worked by means of adits.

The Mountain Mine or Ganister Coal is the most valuable in this district of all the coals below the Arley or Royley Mine, and has been everywhere worked extensively. It ranges in thickness from 18 inches to 30 inches, and is underlain by a valuable bed of fireclay, which in many places contains hard siliceous stone, locally termed ganister. It is the only coal now worked on an extensive scale, and is mined at a considerable depth to the immediate east of Rochdale. The Lower Foot Coal, about 30 feet below it, separated by black shale, is not present everywhere in the district. It has been mined on a small scale at Ogden. The Mountain Mine or Ganister Coal is usually overlain by 36 feet of black shales, above which comes the Bullion or Upper Foot Coal, remarkable for its roof, which is always extremely prolific in shell remains. The roof consists of black shale containing large calcareous nodules known as 'bullions' in which well-preserved *Goniatites* are plentiful. Though seldom exceeding 1 ft. in thickness, this coal, with its distinctive roof, has been found to be remarkably constant over the whole area.

Above the Bullion Coal and the shales which overlie it, in the southern part of the district, is a hard flaggy massive sandstone which forms the prominent scarp of Helpet Edge, and is also well-exposed in Tunshill. Owing to its strong development in the former locality Professor Hull[1] has termed it the Helpet Edge Rock.

To the north of Littleborough, however, the Inch Mine Coal occurs at about this horizon, and overlies a valuable seam of fireclay, 9 ft. thick, which is being mined at the Starring Mine, 1½ miles west of Littleborough Church.

The Forty Yards or Upper Mountain Mine Coal is the highest coal of any importance in the Lower Coal Measures. It is represented throughout the district, and though seldom exceeding 1 ft. in thickness has been worked in several localities. It is at present being mined on a small scale at Ogden. Massive flagstones and shaly mudstones intervene between the Forty Yards Coal and the top of the Lower Coal Measures. The former are being quarried for building and paving stones to the east of New

[1] E. Hull, 'The Geology of the Country around Oldham' (*Mem. Geol. Surv.*), 1864, p. 16.

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Hey, while the shaly mudstones are being extensively worked for bricks close by New Hey Railway Station.

The Middle Coal Measures form a small inlier to the immediate east of Rochdale. The Arley (or Royley Mine) Coal, which is about 4 ft. thick, has been worked at Belfield Colliery, but owing to the ground being much cut up by faulting, and the great variability in the coal, due to impersistent shale partings, these workings have now been abandoned.

The Glacial deposits cover a considerable portion of the lower ground but are absent from the higher ground at Shore Moor, Walsden Moor, Blackstone Edge, Bleaked Gate Moor, and also on the moorlands east of these localities. That these areas have never been glaciated is confirmed by the fact that wherever a section is exposed under the peat on these moorlands, the surface of the grits is found to be covered with a thick deposit of undisturbed kaolinised 'head' which is absent or has been considerably modified in the glaciated districts.

Mr. Lloyd was engaged on the Yorkshire border north of Todmorden. This area comprises the upper part of the old Yoredale Series and the lower members of the Millstone Grit. The ground is entirely free from drift, except for a few thin patches of gravel and blue clay and scattered erratics reported to have been seen in excavations below the alluvium of the Calder between Todmorden and Hebden Bridge. The tops of the moors have a covering of peat varying in thickness from 4 to 10 feet, in all cases overlying 'head,' which on the lower slopes of the moors and in the upper part of one valley attains a remarkable thickness.

No persistent coal has been found associated with the Kinderscout Grit in this area, but there is evidence in a few places on the moorlands around Walsham Dean and Widdop, of an impersistent thin coal near the top of the Grit. This is probably represented by the four-inch coal recorded in the dam sections of Walsham Dean reservoir, where it is associated with a lenticular bed of shale near the top of the Kinderscout Grit.

An unusual feature in the Kinderscout Grit is the presence, at its base, in Eaves Wood and near Hardcastle Crags, of variously textured beds of highly calcareous grit.

The Third Grit beds for the most part form the high ground frequently as cappings to the moors; no trace of coal has been found in them in this area, though a fairly persistent seam is present in the lowest of the Third Grit sandstones east of Hebden Bridge.

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4. Cumberland District

Headquarters : Whitehaven.

Bernard Smith, M.A., District Geologist.
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} Geologists.

Carlisle and Silloth District

The re-mapping of the Old Series Sheet 107 S.E. (New Series 17) has been undertaken by Messrs. Maden and Trotter and more than half completed. The greater part of this area is covered by glacial and recent deposits, the exposures of solid rocks being confined to stream sections along the river valleys upon the eastern border.

NEW RED SERIES

Owing to the exceptionally dry summer Mr. Trotter was enabled to examine more exposures of solid rock than are usually visible along the watercourses. The rocks comprise, in ascending order, St. Bees Sandstone, Kirklinton Sandstone and Stanwix Shales and Marls, and are usually referred to the Triassic Series, the lower sub-division being regarded as Bunter and the upper ones as Keuper. Into the merits of the correlation it is impossible to enter at this stage, and it must suffice to say that the 'gypseous shales' of the Abbey Town boring[1] are thought to represent the Stanwix Shales, as shown on the old Geological Survey map.

The St. Bees Sandstone proved to be a compact, angular-grained, frequently micaceous sandstone, with a minor development of thin chocolate-coloured micaceous shales. The sandstone is even-bedded on the whole, although subdued false-bedding is not infrequent. Thicker posts are quarried for building-stone, thinner ones for flags. In colour it is usually brick-red, but the colour may alter rapidly within short distances from brick-red to white.

The Kirklinton Sandstone[2] is most consistently of a bright red to scarlet colour, but, like the St. Bees Sandstone, it alters rapidly within short distances to buff-red and white. It is a soft, highly false-bedded sandstone, calcareous in places. As a rule it is close-grained but often contains layers of large millet-seed quartz grains. Except at its base and at the top, where it conformably passes into Stanwix Shales, it is devoid of shale bands. It is exposed at several points in the district and underlies Carlisle

[1] 'Geology of the Country around Carlisle' (*Mem. Geol. Surv.*), 1899, Appendix I., p. 52.

[2] For differences between St. Bees and Kirklinton Sandstone see Prof. J. W. Gregory 'The Red Rocks of a Deep Bore at the North End of the Isle of Man,' *Trans. Inst. Min. Eng.*, vol. lix., 1920, pt. 2, p. 160.

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as a white or grey sandstone of considerable thickness (*see also* p. 63).

Mr. Trotter has examined two critical sections, showing the junction of the St. Bees Sandstone with the overlying Kirklinton Sandstone: (i) along the River Line eastward from Cliff Bridge (Old Series 106 S.W.—a mile and a half N.E. of Westlinton) Kirklinton Sandstone is seen until Broomhill Farm is reached, when, for a distance of a quarter of a mile, beds of Kirklinton Sandstone type alternate with beds of St. Bees Sandstone and Shale type. Farther eastward nothing but St. Bees Sandstone is visible. The thickness of these passage beds is 250 feet. (ii) In Carwinley Burn, 200 yds. N.E. of the road from Carwinley Mill to Low Moat (Old Series 107 N.E.), and 40 to 50 yds. S.W. of a small bridge, another junction of the two types is seen. Here the change is much sharper, only 25 ft. of passage beds being present. North-west of this critical section the river cliffs are of St. Bees type, and south-west of Kirklinton type.

A curious section of Kirklinton Sandstone in Skew Bank, north of Grinsdale, shows alternations of well-bedded to highly false-bedded greyish-white sandstone with traces of red and buff bands, and some black beds of calcareous sandstone of rather coarser grain. These black-stained layers occur elsewhere and may on analysis prove to be due to the presence of manganese. Irregular patches of grains cemented by calcite stand out on weathered faces and give a false appearance of brecciation.

The Stanwix Shales and Marls apparently succeed the Kirklinton Sandstone with conformity. In an old river-bluff 200 yds. south-west of Cliff Bridge, a 4-inch bed, consisting of thin alternations of Kirklinton Sandstone and Marl, occurs between typical Stanwix Marls above and Kirklinton Sandstone below. Again, although no such passage bed is visible at the junction exposed 100 yds. east of Westlinton Bridge, there is no sign of unconformity.

Stanwix Shales are red and green in colour and consist of two types—arenaceous and argillaceous. Both are calcareous, but in varying degree. Near the base the sandy type predominates, and beds of red, micaceous and slightly calcareous sandstone are not uncommon. Thin beds of impure limestone appear in the more argillaceous parts at a higher level.

A point worthy of note is the tendency of the marls to develop 'skerries.' Three or four feet of sandy marls are overlain by about one foot of rapid alternations of red and tea-green shales, this sequence being repeated several times. This development, however, cannot be said to be characteristic of the marls

Most of the sections in this series occur in the bank of the Eden, notably between Etterby Scaur and Rockcliffe. Between these points the marls form two synclines, the adjacent limbs of which, with the aid of a small fault, bring in the Kirklinton Sandstone at Skew Bank and Grinsdale.

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In the western part of the area, mapped by Mr. Maden, no fresh information has come to light as regards the New Red rocks. Knowledge of the rocks is dependent on two small borings —the one west of Bowness[1] and the other at Kelsick Moss near Abbey Town.[2] Discussion of these bores is left until further field work is done. It is assumed, however, in the absence of any proof of the presence of Rhætic Beds, and after weighing up the available evidence, that the highest New Red beds in the district are the Stanwix Shales and Marls.

LOWER LIAS

The western part of the Liassic outlier west of Carlisle, almost entirely concealed by drift, was mapped by Mr. Maden, who was enabled, by the presence of a more or less persistent feature forming the outer slopes of the drift-covered Liassic plateau, to draw a provisional boundary between Lias and New Red rocks. A small exposure of the Lias occurring in the bed of a stream about 700 yds. north of Thornby consists of fine-textured bluish-grey soapy shale dipping northward at a low angle. It yielded characteristic Liassic lamellibranchs.

GLACIAL

In the district north and north-west of a line drawn from about Rockcliffe to Westlinton, Mr. Trotter finds that the Glacial deposits consist of a series of sands and gravels resting upon an upper boulder-clay separated by a second or 'middle' series of sands and gravels from an underlying boulder-clay.

Both boulder clays are of the red sandy type prevalent whenever ice has passed over Triassic sandstone for some distance. They both contain the same suite of boulders, viz. grey and green Silurian grits (abundant), Criffel and Dalbeattie granites (common), Penrith Sandstone, St. Bees Sandstone, grey and reddish Carboniferous sandstone, a conglomerate (typical of Lower Silurian of Kirkcudbright), local rocks (frequent), and Carboniferous limestone (rare). The maximum thickness of the upper clay is 20 feet.

Where boulder-clay overlies the Stanwix Marls it is much stiffer and more plastic than elsewhere. All the brickfields situated north of Carlisle occur in clay overlying Stanwix Marls.

The middle sand and gravel series consists of gravel, coarse sand, fine false-bedded sand and thin impersistent beds of laminated loam and clay. Where not overlain by the upper boulder-clay they give rise to a featureless plain. The fact that the junction between the lower boulder-clay and the sand and gravel is uneven and pockety, the pockets containing gravel, taken together with the fact that their altitude increases to the north-west, seems to point to their being either (1) part of an outwash-fan thrown out by an ice-sheet lying to the north-west, the laminated

[1] 'Geology of the Country around Carlisle,' *op. cit.*, p. 30.
[2] *Ibid.*, p. 53.

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clay being deposited in shallow pools, or (2) part of a glacial lake deposit. Sand and gravel were first deposited on a land surface. As the water accumulated a shallow lake was formed in which the finer sand and laminated clay were deposited. It is hoped that during the coming field-season further evidence will be obtained which will elucidate this problem.

The upper boulder-clay in its advance has in places contorted and incorporated the beds of sand and gravel. Evidence of the presence of a middle series of sands and gravels, with laminated clays, has been obtained at Carlisle and in the banks of the Eden at Grinsdale; the magnitude of the second advance of the ice-sheet cannot be ascertained definitely until further mapping has been carried out. At Botcherby, Carlisle, the dark red laminated clays, overlain by bedded sand and gravel, are exposed to a thickness of at least 8 feet. Their upper surface is pockety. The clays apparently mark the site of a glacial lake.

Long, snake-like, steep-sided, conical ridges, composed of pure red sand with gravel, the bedding-planes of which are approximately parallel to the slopes of the ridges, rest upon the top boulder-clay and mark the final retreat of the ice from the district. Up to the present only one of these eskers has been mapped in the Carlisle Sheet, but several appear west of it over the Scottish border. The direction of the ridges is a few degrees south of east.

In those districts where the middle sand and gravel is absent the boulder-clay occurs in mounds and ridges, the general direction of their long axes being east and west. Northwards a pronounced drumlin-like topography gives place to one characterised by long steep-sided ridges up to 80 feet in height, and in many cases a mile in length. Taking into consideration the suite of boulders recognised and the trend of the drumlins, ridges and eskers, there can be no doubt that the ice that covered the district emanated from the mountainous country around Criffel.

Farther west, in the Kirkbride district, Mr. Maden reports that drift completely masks the solid rocks. It is in the main a red, or reddish-brown, boulder-clay, generally of a sandy character, although in places it is stiff and clayey. The erratics all appear to be of Scottish origin from the Criffel-Galloway area, and are chiefly grey, green and purple grits and grey and pink granites, and two types of conglomerate, one typical of the Lower Silurian, and the other of the Calciferous Sandstone series of Kirkcudbrightshire. No Lake District types have been noticed. In the Bowness area the clay is not very stony, whilst on the shore, underlying Herdhill Scar (at the railway viaduct) it is a strong red stoneless clay.

As in the Carlisle district, the boulder-clay takes on one of two forms—the drumlin, or the elongated ridge. Examples of the former are to be seen at Cardurnock, Rogersceugh, Drumburgh, Lawrenceholme and Wedholmehill, whilst typical ridges are displayed at Anthorn, Little Bampton and Aikton.

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The major axes of the ridges and drumlins exhibit marked parallelism. In the Cardurnock peninsula the direction is S.W. to N.E. Near Fingland, Little Bampton and Aikton it is W. to E. Near Parton (about 2 miles N.E. of Wigton) it is approximately W.N.W. and E.S.E. These changes in direction indicate differences in the movement of the ice. The boulder-clay is thinner on the western margin of the Liassic outlier, and the solid rock begins to appear in stream sections farther east.

In many places the boulder-clay has included patches of gravel with indefinite boundaries and featureless contours. These are considered to be remnants of englacial and sub-glacial gravels incorporated in the till during movement. At Fingland and Aikhead Lowhouse (about 1 mile N. of Wigton), however, small mounds of gravel can be mapped separately.

POST-GLACIAL AND RECENT

Marine Alluvium.—After the close of the glacial period the land bordering the Solway stood lower with respect to sea-level than at the present day. The Solway must have been much wider, for the waters encroached upon many miles of the land surface and the tide entered the river valleys far above its present limits. The first marine deposits laid down have since been elevated to an average height of 30 ft. above sea-level, but this took place at several periods and has given rise to a series of terraces as follows :—

	Height above O.D. Ft.
River Wampool and Cardurnock Peninsula—	
Raised Beach	33–36
3rd Terrace	28–30
2nd Terrace	19–21
1st Terrace	16–17
Rivers Eden and Esk :—	
3rd Terrace A.	26–30
3rd Terrace B.	22–26
2nd Terrace	19–22
1st Terrace	16–19

In the Cardurnock Peninsula and the drainage area of the Wampool Mr. Maden finds that the alluvium consists of warps resting upon boulder-clay and giving rise at each stage to a perfectly flat countryside. The 1st, or newest terrace, is composed of a dark brown mud or sandy mud with many fine fibrous roots, whilst the older warps are greenish clays or clayey loams with brown mottling around the rootlets, some of which are still visible; this mottling may be seen commencing in the newest warps. This terrace supports a very fine grass, free from weeds, which is in great demand for high-class bowling greens and tennis courts, &c.

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The warps are best studied along the present shore-lines, where in places, such as Drumburgh and Boustead Hill, they are being corraded by the Eden and give rise to a low cliff and a talus of blocks up to 6 by 3 by 3 ft. in size. They are finely laminated and horizontally bedded as seen on weathered surfaces, but on cutting into them freshly the lamination is not visible. On the shore the lamination is clearly brought out, since the fine clayey layers are more resistant to denudation than the sandy ones. In inland sections the warp generally appears as a dark grey, or blue-grey sandy clay. If no mottling appears in the latter it can be taken as indicating the proximity of the boulder-clay, and generally is in the 3rd terrace.

In places the warp is quite a strong bluish stony clay and these patches are considered analogous to the ' scars ' which are at present in process of formation in the Solway, being strong courses washed into the warp from neighbouring islands of boulder-clay.

The 3rd terrace is contemporaneous with a well-marked raised beach (*see below*) with which it appears to interdigitate. In the vicinity of Scargravel Point the terrace rests upon the beach. Near Solway House (south of Cardurnock) the beach is seen upon the terrace. The 2nd terrace always forms a notch in the raised beach or the 3rd terrace, whilst the 1st terrace invariably notches the 2nd terrace and appears to be quite recent. Mr. Trotter finds that in the north-eastern district the upper terrace is divisible into two steps. The warps here consist of laminated, grey, argillaceous to sandy alluvium with varying amounts of carbonaceous material, and the three terraces can be traced up the rivers Sark, Esk and Eden. The older terraces stretch farthest up the river valleys.

From a casual survey one would conclude that they were all river terraces, but systematic mapping shows that the alluvium of the rivers overlies the warps; also, in the case of the river Esk, the first river terrace overlies the 3rd terrace of warp.

The separation of these broad spreads of warp from the river alluvium, which is of quite a different character, is of some economic value; the 3rd terrace in particular is capable of bearing crops of cereals, roots or tubers, whilst the river alluvium is mostly under pasture.

The raised beach associated with the 3rd terrace has been traced by Mr. Maden from Bowness, where it rests against the truncated edge of a ridge of boulder-clay, continuously round the Cardurnock peninsula to Anthorn, a more extensive spread than was mapped during the old survey. Its altitude is between 33 and 36 ft. above O.D. Its surface is piled up into a series of parallel ridges or ' fulls ' of gravel (similar to those at Dungeness) well exhibited between the viaduct at Bowness and Scargravel Point. The direction of the ridges conforms in general with the seaward contour of the peninsula.

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The beach consists of sand and gravel in which the stones are all from the boulder-clay. They have not suffered much from attrition.

In its southern portion the beach is more stony and less sandy than in the north. It was apparently not formed against a shore-line, but as a spit or 'hook,' running seaward on the flank of the current, the warp being laid down in the stiller waters behind.

Blown Sand.—Blown sand is found at Herd Hill, ¾ mile N. of Cardurnock village, and in Long Wood to the immediate S.E. of Cardurnock. A small patch occurs also about 200 yds. N. of Long Wood.

It occurs in rounded ridges as a bright yellowish-brown sand with a few small stones. Current bedding at high angles is seen in sand pits in each locality. The major axes of the ridges are in the same direction as the ridging of the beach upon which they rest; the latter has probably modified the effect of the wind and brought the blown sand into line with it. The sands are no longer moving and are completely grass-grown; they may belong to the raised beach period.

Recent Alluvium.—(1) Marine.—The sandbanks of the Solway and the sand of the estuaries have been mapped as marine alluvium as far as those points where the estuaries assume the characters of rivers at all states of the tide.

Mr. Maden finds that this alluvium consists of a pale yellow sand, chiefly of quartz, with carbonaceous matter, and often littered with drift-wood. In the neighbourhood of Bowness it is in places fine and muddy. It contains numerous 'scars' (shingle and boulders), some of which, like those south of Cardurnock, are situated on boulder-clay. The 'scars' are constantly changing position, as also are the low-water river channels.

(2) River.—Mr. Trotter reports that broad stretches of alluvium occur along the courses of the rivers Esk, Line and Eden, and, to a minor extent, the river Sark.

The alluvium occurs as a series of terraces which are doubtless due to the uplifts that have given rise to the terraced warps of the coast-line (*see above*, p. 48). The oldest terraces are of gravel and are distributed at intervals; a good example occurs at Longtown, rising to 20 ft. above the present alluvium of the river Esk. Part of H.M. Munitions Factory, Gretna, is situated on two more recent terraces of the Esk. The corresponding terraces of the Sark are gravelly, but contain a greater percentage of sand, whilst those of the Eden contain clay or clayey loam as well as sand and gravel. The modern alluvium forms a grey sandy loam.

In the Kirkbride district the alluvium examined by Mr. Maden consists generally of a reddish brown loam, derived from denudation of the boulder-clay.

Peat.—Long after the rest of the country had been brought under cultivation the district near the Scottish border remained

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as the Romans found it, covered by vast forests and swampy marshes, of which the peat-mosses of to-day are the shrunken remnants. Peaty soil found as far as 2 miles from the boundaries of the mosses shows that at no distant date the latter covered a greater area than they do to-day. The mosses occur in enclosed hollows between ridges of boulder-clay or upon flat country, notably the marine warps, which have proved difficult to drain. About 13 sq. miles of peat have been mapped, chiefly in the Cardurnock, Bowness, Glasson, Solway, Rockcliffe and Drumburgh Mosses; and, wherever possible, the boundaries between cut and uncut peat have been drawn.

The peat is used locally for fuel, and is exploited commercially, in the Wedholme and Solway Mosses for peat-moss litter and in the manufacture of molasses meal, oil cake, manure and brown paper. The method of cutting in the latter case is on the Dutch system.

Whitehaven District

The remapping of the Whitehaven Sheet (Old Series 101 S.W., New Series 28) was commenced by Messrs. Smith, Dixon and Eastwood, and considerable progress made during the year. Mr. Maden also took a share in the work. The complexity of the geological structure, however, renders it necessary to postpone judgment upon many points until more evidence has been collected.

The solid rocks consist of a series of New Red rocks lying unconformably upon the Carboniferous—comprising Coal Measures, Millstone Grit and Carboniferous Limestone Series—which in their turn are unconformable upon the Skiddaw Slates.

SKIDDAW SLATES

The rocks that form the western margin of the fells between Ennerdale and Loweswater are shown as Skiddaw Slates on the Old Series Geological Survey maps, and, in default of proof of definite age, this name may be retained. Mr. Dixon, who examined this tract of country, finds that the rocks vary in composition from clay-slates to fine-grained sandstones and striped quartzites, with rare and thin bands of fine conglomerate, the whole coloured grey; parts weather white. No fossils have been found, despite wide exposures of bedding-planes in slates little affected by cleavage or heat. Nor has it been possible to determine a sequence; hence both true age and structure remain unknown. Over most of the area the beds show a north-westerly dip of from 30° to 60°, which is probably illusory, for in a few clear sections it is seen to be the inclination of the limbs of isoclinal folds.

Hornfels and spotted slate, results of the intrusion of the Ennerdale Granophyre,[1] are more widely developed than is shown on the former map. Their distribution is irregular,

[1] The petrological characters of this rock have been described by Dr. R. H. Rastall, *Quart. Journ. Geol. Soc.*, vol. lxii, 1906, p. 253.

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possibly on account of underground extension of the granophyre. No other intrusive rocks have been found by Mr. Dixon in this area.

The mapping of the faults in the slates is important, because some have locally become workable lodes of hæmatite and some are in line with known cross-faults in the Carboniferous Limestone. A sheaf of N.W. to S.E. faults has been described by Mr. Smith in the memoir on the hæmatites of the district,[1] as it has yielded ore at Knockmurton and Kelton Fell. Old workings and trials enable some members to be traced N.W. almost to the Glacial drift of the coastal plain and S.E. to Crossdale Beck, but there is little doubt that the sheaf, though probably carrying no ore, continues in the latter direction along the S.W. faces of Banna Fell and Herdus.

A parallel fault appears to run from the south end of Hen Comb to the Cogra Reservoir, and another is suggested N.E. of Blake and Owsen Fells, in line with the great south-westerly downthrow shown on the old map as dislocating the limestone-outcrop of Scalesmoor and Dean. Neither fault is exposed or known to be mineralised.

On the south side of Ennerdale Water Mr. Maden found that the Skiddaw Slates fell within the metamorphic aureole of the granophyre, and consisted chiefly of grey-green to pink striped hornfels, traversed by a few veins of hæmatite (formerly worked for ore) and at least one dyke.

Farther south near Water Mill to the south-east of Cleator Moor Mr. Smith discovered a suite of dykes, apparently of acid type and vesicular, trending from north-east to south-west in uncleaved but highly folded Skiddaw Slates. These are not shown upon the Qld Series map.

CARBONIFEROUS LIMESTONE SERIES

The outcrop from Yeathouse to Pardshaw has been examined by Mr. Dixon, who also made use of many records and the cores of borings in the Lamplugh district.

It is obvious that along this outcrop, where valuable deposits of hæmatite are being worked and exploration is being actively pushed northward, a knowledge of sequence and structure is vital to the mining industry and that conclusions under either head must be preceded by patient accumulation of evidence.

The seven limestone bands recognised by Mr. J. D. Kendall persist throughout; the 3rd and 4th beds, which in places elsewhere are grouped together as the 3rd (making a total of six) are distinct. The detailed lithological and faunal characters of the whole series have been described recently by Mr. C. Edmonds,[2] of Moor Row, who by their means has been able to compare

[1] 'Special Reports on the Mineral Resources of Great Britain,' vol viii. (*Mem. Geol. Surv.*), 1919, pp. 164–7, fig. 29.

[2] 'The Carboniferous Limestone Series of West Cumberland,' *Geol. Mag*, 1922, pp. 74–83, 117–31.

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the sequence with that at Alston Moor and with the zones based by Vaughan and Garwood on the developments in the S.W. and N.W. provinces. The Survey is greatly indebted to him for freely communicating his results before publication and for pointing out, on the ground, the features of the different bands. His criteria have been tested, and although, as might be expected, all of them do not appear in every boring, by their means it is now possible (unless the original characters of the limestones have been destroyed by hæmatitisation or dolomitisation) to recognise the horizons of even fairly short lengths of core. At some levels, indeed, single beds are sufficiently distinctive to be identified. For details reference should be made to his paper. The following are points of some general interest.

The Bottom, or 7th Limestone, is remarkably persistent, despite the strong unconformity at its base with the 'Skiddaw Slates.' Its horizon is the *Nematophyllum minus* subzone, or S_2, which is the level also of the base of the Carboniferous Limestone around the northern end of the Lake District.[1]

This persistence testifies to the remarkably even character of the platform of older rocks on which the limestones have been laid down. The horizon was evidently one of widespread, though shallow, marine transgression; it forms the base of the Carboniferous Limestone most frequently also along the North Crop in South Wales.

The Clints, or 4th Limestone (D_1 and D_2 parts), includes a number of levels at which the upper surface of a bed of limestone, underlying a clay-mudstone ('mottled shale'), or sandstone, is penetrated by 'pipes' or 'pot-holes' up to several feet in diameter and several yards in depth. The pipes are filled with mudstone or sandstone like the overlying bed and recall those observed by Greenly in the D_2 and D_3 limestones of Anglesey.[2] The piping, it is agreed, has been contemporaneous. Prof. W. H. Hobbs suggests (p. 615) that the Anglesey pipes are similar 'to the sand funnels produced by the derangement of ground water by earthquakes,' whereas Mr. Edmonds concludes that the Cumbrian pipes are due to repeated incidents of emersion and subaerial erosion. Channelling, observed by the latter in one of the limestones, might be caused by earthquake-waves, as Greenly remarks of some planes of erosion in Anglesey. But the fact that all the known pot-holes in Cumberland are filled with continental or lagoon deposits points directly to elevation. They may be parallelled with the piping and subaerial erosion of limestones at the junction of the Lower and Upper Avonian at West Williamston, Pem.,[3] and Pendine, Carm.,[4] and at that

[1] K. W. Earle, *Abstr. Proc. Geol. Soc.*, No. 1076, 1921, p. 10

[2] 'The Geology of Anglesey' (*Mem. Geol. Surv.*), vol. ii., 1919, pp. 613–6, pls. XXXVIII. and XXXIX., figs. 289 and 290.

[3] 'The Country around Haverfordwest' (*Mem. Geol. Surv.*), 1914, pp. 141–2, pls. I and II.

[4] 'The Country around Carmarthen' (*Mem. Geol Surv.*), 1909, pp. 81–2.

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of the Upper Avonian and Millstone Grit at Haverfordwest[1] and Ifton, Mon.,[2] both of which junctions are unconformities.

The Top, or 1st Limestone, Mr. Edmonds shows, is possibly D_3, and corresponds to the Main Limestone of the Yoredale Beds. The shales and sandstones interbedded with the limestones yield a few plants, and it is hoped that, by means of these and the flora and fauna of the Millstone Grit above, it may be possible to help towards a comparison of the classifications—based on different groups of organisms by Vaughan, Garwood, Kidston and Wheelton Hind—of the various deposits that intervene between the Carboniferous Limestone and the Coal Measures.

The distribution of hæmatite has long been known to depend partly upon fault-planes and similar fissures, partly upon the presence of impermeable shales. No evidence was obtained last year that it had been materially affected by the kind of limestone subject to replacement. It is certain that in ore-bodies many different kinds of limestone, such as pseudobreccias, coral and crinoid bands, have been altered. A parallel may, perhaps, be drawn with ' subsequent ' dolomitisation which has frequently accompanied hæmatitisation. Such dolomitisation acts selectively on different constituents of a limestone only where it is incomplete.

A small tract of Carboniferous Limestone surveyed by Mr. Eastwood forms an outlier at Hensingham, but the upper part only of the formation is exposed, the lower portion being cut out by a fault bringing in St. Bees Sandstone on the east. A fault on the north, by Overend, throws Millstone Grit against the Limestone; while on the south-east, at Netherend, the inlier is terminated by the Ingwell fault which introduces Trias. Exposures depend upon quarrying and boring operations. The quarries are disused, but the largest furnishes a good section in the 1st Limestone succeeded on the west by Millstone Grit. A small quarry, lying farther east, shows the parting (shales and sandstones with a thin coal) between the 1st and 2nd Limestones, and also a few feet of the top of the latter. The 3rd Limestone is exposed indifferently farther south-east.

The inlier has been extensively prospected for hæmatite but the bores have failed to reveal payable ore. Borings of recent date have proved the full thickness of the Limestone Series to be 700 ft. between the Millstone Grit and the Skiddaw Slate.

Exposures of Carboniferous Limestone are scarce in the area mapped by Mr. Smith between Moor Row and Bigrigg.

The 1st Limestone, with west-south-westerly dip, is exposed in some old crop-workings a few yards N.E. of the disused Gutterby Pit. The Bigrigg-Ingwell Fault brings it to outcrop again farther west, south of the Pallaflat Railway line, where it appears, dipping in the same direction and capped by Millstone Grit, in a range of old quarries.

[1] ' The Country around Haverfordwest ' (*Mem. Geol. Surv.*), 1914, p. 151.

[2] *Geol. Mag.*, 1921, p. 157, pl. II.

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Borings at Bigrigg prove that the total thickness of the Carboniferous Limestone in this district is from 750 to 760 ft.; and it may be pointed out that the individual limestones from the 1st to the 6th, or 1st to the 7th, according to the grouping, have similar characteristics to those in the Yeathouse-Pardshaw area.

The limestone is extensively mineralised, some of the chief West Cumberland haematite mines occurring in this neighbourhood.

MILLSTONE GRIT

The strata, from a hundred to two hundred feet in thickness, lying between the Udale Coal and the top of the 1st Limestone are taken provisionally as the Millstone Grit Series. In the Hensingham area Mr. Eastwood finds that typical grit, as known in Lancashire and Yorkshire, is not well developed, the strata consisting mainly of sandstone and dark shales with some thin lenticular bands of limestone. The lower part of the formation, showing rough sandstone, is exposed around Overend; that capping the above-mentioned large limestone quarry yields numerous casts of plants of which the commonest is *Lepidodendron*. The upper part of the series is best seen in Snebro Gill, Hensingham, though sections occur in the gills southwards to Chapel House. Snebro Gill is, for the most part, floored by a dark earthy limestone. This is succeeded by dark shales with lenticular bands of limestone varying from dark earthy types, occasionally crowded with brachiopods, to a pale shaly type made up almost entirely of encrinite stems. The shales contain occasional sandstones.

In the area farther south, mapped by Mr. Smith, a bore-hole south of the mineral railway-cutting (Pallaflat Railway) at Bigrigg proved approximately 150 ft. of the Millstone Grit Series, with a group of sandstones both at the top and bottom, and shales with occasional sandstones and ironstones between. Black goniatite shales occur about half-way down this series and are exposed[1] in the cutting a few yards S.W. of the bridge over the railway. Goniatites occur at other horizons, in ferriferous nodules in red and purple shales, but the fossiliferous horizons are by no means constant. The lowest bed is a mottled sandy shale 2 ft. thick, but this is absent in places. The palæontological evidence has yet to be worked out.

An old quarry, situated 130 yds. E.S.E. of the bridge, shows 6 ft. of grit on thin shales, on 12 ft. of the 1st Limestone.

Farther west the Breccia, as proved by boring, overlies a thickness of 424 ft. 6 in. of purple shales, red, grey or mottled micaceous shales and laminated sandstones, with occasional beds of coarse red and grey felspathic grit and white fine-grained sandstone. Black shales occur at intervals towards the base and are in some cases fossiliferous. The lowest bed here, overlying

[1] Our attention was drawn to this locality by Mr. C. Edmonds.

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the 1st Limestone, consists of 3 ft. of dark fossiliferous shale and mudstone, beneath a medium-grained felspathic grit.

The lower 180ft. at least of this series, below the top of a bed of coarse felspathic grit, must be regarded as Millstone Grit; most of the beds above, chiefly micaceous shales and shaly sandstones, may represent the lower part of the Coal Measures stained by iron-bearing waters from the New Red Rocks.

COAL MEASURES

The Whitehaven coalfield is much broken by faults of considerable throw, though in places of small lateral extent. On the whole, at Whitehaven, the measures incline westwards, while south of Saltom their dip swings round to the south-west and soon brings on a thick cover of post-Carboniferous rocks. North of Whitehaven the measures frequently dip inland, and only take on a pronounced westerly dip when the coast is reached. This dip is greater than the slope of the sea-bottom, and thus enables coals to be wrought with comparative safety beneath the sea-bed. The workings of the Whitehaven Collieries extend seawards for a distance of over four miles from the coast.

The Coal Measures of the southern part of the coalfield, examined chiefly by Mr. Eastwood, fall naturally into two subdivisions, the lower containing the chief seams of coal, and the upper little or no coal. The former consists of grey types of sediments common to the Lower and Middle Coal Measures of the neighbouring coalfields, but at this stage all the coal-bearing strata will be described as the Productive Measures. In the latter or upper sub-division, the prevalent tint is purplish, shading to red, grey and brown. Sandstones usually predominate, though the upper part contains much shale and occasional bands of limestone with *Spirorbis*, thus linking the sub-division with the barren Upper Coal Measures of the Midlands. This group will be described as the Whitehaven Sandstone, and its relation to the Productive Measures will be considered at a later stage.

Productive Measures.—In the Whitehaven area Productive Measures attain a thickness of upwards of 1,200 ft., taking the base at the Udale Coal, the relative position of which, together with that of the prihcipal seams, is indicated in the generalised section, Fig. 1. The measures consist of the usual assemblage of shales, clays and sandstones with occasional ironstones, and numerous seams of coal. They do not differ materially from top to bottom, and are remarkably impersistent. Sandstones frequently pass, both laterally and vertically, into sandy mudstones, shales and fireclay. In general the sandstones are coarsest in the lower part of the group. That immediately above the Four Foot Coal often occurs as a rough grit with quartz fragmehts up to half-an-inch in diameter; that above the Six-quarters Coal as a coarse sugary sandstone; while those at higher horizons—above the Main Band, above the Bannock Band, and above the

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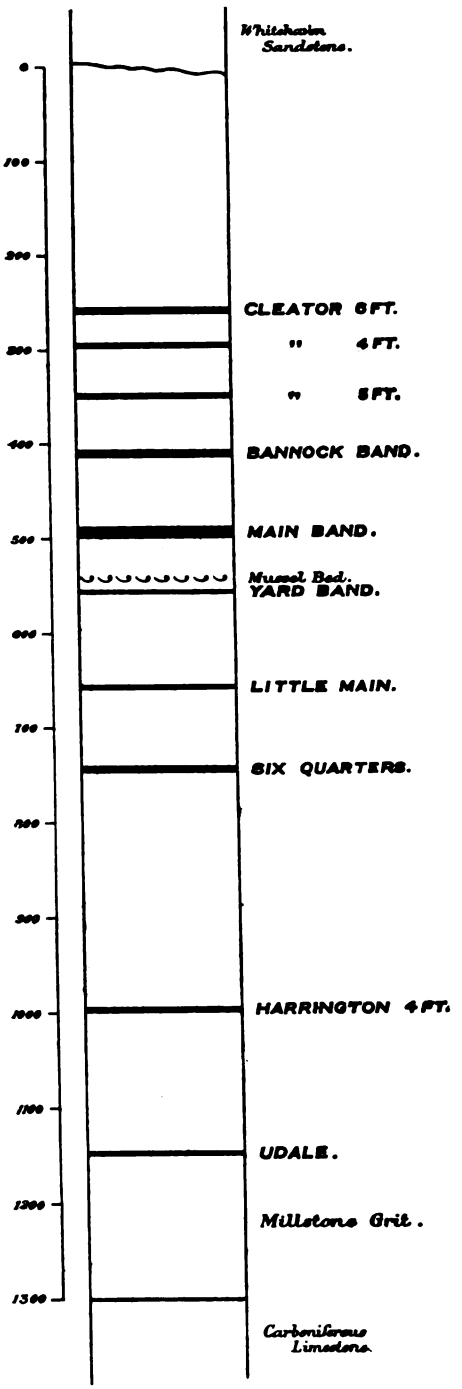

FIG. 1.—*Generalised Section showing the sequence of the chief Coal-seams in the Whitehaven District.* (Depths are given in feet.)

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Cleator Six Foot or its representative—though often coarse, are usually of medium grain. The sandstones vary in colour from white to grey, and weather buff or yellow. The argillaceous beds are as inconstant as the sandstones—black shales in one part of a quarry passing into light clays in another. As a rule, those below the Main Band are of a darker shade of grey than those immediately above that coal, while those above the Bannock Band are frequently pale greenish and bluish grey. Apart from these characters the only approximate index of horizon so far discovered is the Mussel Bed a few feet above the Yard Band. This consists, when well developed, of a dark ironstone, about one foot in thickness, closely packed with large *Carbonicola*, but is frequently accompanied, or replaced, either wholly or in part, by dark shales containing either scattered *Carbonicola* or heart-shaped fish-scales. In boring for coal this bed escapes notice unless special watch is kept. Dark shales with *Carbonicola* occur at other horizons, notably some distance above the Four Foot Coal in Andrews Gill north of Micklam, and about the horizon of the Two Foot Coal around Distington. It will be seen, therefore, that unless a considerable section is exposed or the coals are well developed, it is almost impossible to allocate correctly the position in the sequence.

The coals belong to the bituminous class suitable for household use, general steam raising, and also to some extent for coking. Individual seams vary in thickness and may be split by partings. All are subject to 'nips' and occasionally are entirely wanting over hundreds of acres. In general the lower coals thin away southwards while the upper seams deteriorate in a northerly direction.

The *Udale Coal*, averaging about 3 ft. in thickness in the Harrington area where it was at one time worked, is thin and worthless around Whitehaven. It has been located in Walkmill Pit, and at the surface in Bedlam Gill, Hensingham, where the dark shales above it yield goniatites.

The *Four Foot Coal*, wrought in the past at Harrington Collieries, is almost valueless at Whitehaven, being either a thin band or split by shales.

Thin chance seams occur between the Four Foot and the Six-quarter seams and may be seen associated with dark platy shales at the foot of Middle Gill, in Andrews Gill and around Common End, Distington.

The *Six-quarters*, also known as the *Yard Seam*, is the most wrought of the seams below the Main Band. It averages about 3 ft. of workable coal, with a few inches of 'rattler' or bastard cannel at its top. This seam with its rough sandstone cover crops out below Moresby House, under Middle Gill Farm, Barngill Quarry, the gill by Harrington Mill and at Common End, Distington.

North of Low Scalegill, between the railway and High Low Hall, Mr. Smith notes that the Low Main or Six-quarters Coal

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dips south-eastward along a line of fault at angles varying from 25° to 65° towards the workings from several old pits. The coal occurs as lenticles nipped-out along the fault-plane. A band of cannel occurs in grey shales at a little distance below the coal.

Though thin seams occur above the Six-quarters Rock, the only one of importance is the *Little Main* or *Two Foot Band*. As the latter name implies, it is only about 2 ft. in thickness, but is frequently worked as it is of good quality. The roof is of shale with a few inches of 'rattler' at the top of the coal, while the floor is generally a good fireclay.

The thin seams between the Little Main and the Yard Band are as a rule valueless. The dark shale roof of one cropping out just below the railway embankment in Middle Gill has yielded *Lingula*, but this horizon has not been located elsewhere.

The *Yard Band*, with two or three feet of coal, though sometimes worked, is not a high-grade seam. It crops out at the east side of the railway embankment in Middle Gill, at several places around Distington, also with good Mussel Bed above it in the White Park of Whitehaven Castle, and the banks of the Keekle near Priest Gill; while the Mussel Bed is seen near the fault bringing in the Breccia at Howth Gill, Frizington.

The Yard Band with both Fish and Mussel Beds has been detected by Mr. Smith in Bearmouth Gill and Benhow Wood.

No seams of importance lie between the Yard and Main Bands, though thin beds of coal and cannel occur.

The *Main Band*, averaging five or six feet of coal and sometimes attaining a thickness of ten or twelve feet, is the most valuable seam in the district. Some cannel is frequently present at the bottom of the seam. The roof is variable: it frequently consists of light blue-grey mudstone with posts of sandstone, overlain by a considerable thickness of sandstone. The outcrop of this seam was exploited during the recent mining dispute at Middle Gill, below Castle Rigg, in Stubbs Gill 'lonning' and Boonwood in the neighbourhood of Distington, and below High Wreah in the banks of the Keekle. The sandstone above it—sometimes referred to as the Main Band Rock—is well developed and exposed in the River Keekle above Walk Mill.

Mr. Smith finds that the Main Band, worked so extensively in the old Howgill Collieries, crops out on the west side of the St. Bees-Whitehaven valley beneath Greenbank, and was dug during the recent dispute at Bearmouth Gill near Coalgrove Bank, where it dips west-south-west. In the Bearmouth gully the Yard Band and an underlying coal were also laid bare.

Main Band coal has been worked from Ladysmith Shaft as far south as Hannah Moor and Rottington in the Whitehaven Colliery under St. Bees Headland.

In the valley floor the coal was worked at the old Scalegill Colliery between Stanley Pond and Scalegill Beck.

It was also worked at the Whinnyhill Colliery near Cleator Moor.

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The *Bannock Band*, frequently split by one or more partings, and yielding five or six feet of coal of fair quality, is reported by Mr. Eastwood to have been wrought to a rather less extent than the Main Band at the principal collieries. It crops out with that seam at the foot of the slope along the west side of the St. Bees valley, though the actual basset is masked by boulder-clay. The overlying sandstone, the 'Bannock Band Rock,' is somewhat similar to that above the Main Band except that it is in places of finer grain and of bluish-white tint. This rock appears on the beach north of Lowca Point, and in the disused quarry at Sand Close near Walk Mill.

Mr. Smith examined faulted outcrop workings in the Bannock Band about 100 yds. east of the old Moss Pit, west of Coalgrove Bank. The coal at one point was 8 ft. in thickness, the roof being a black shale with fish scales. The Bannock Band with associated coals was also exposed, dipping south-westward, in surface-workings in Benhow Wood, where it is repeated by a fault aligned almost directly with the fault that throws in the opposite direction, bringing the Coal Measures against the Magnesian Limestone (p. 65) in Bellhouse Gill.

Mr. Eastwood reports that the seams above the Bannock Band are of less value than those below, and are frequently split by partings of shale and clay. They and the measures between them are even more variable and less easily recognisable than the seams below. The best section in this belt of strata is exposed in the quarry of the Whitehaven Brick Co., about one mile south of Whitehaven, though smaller exposures may be noted in the cliffs and on the beach both north and south of the harbour. Though the seams were wrought in the early days of mining, they are not exploited on a large scale as a rule at the present time. The principal seams have been worked in the Cleator and Frizington district under the names given in the section on Fig. 1, p. 57. The lowest, or *Cleator Moor Five Foot*, has been tried at Oatlands Colliery, where it is known as the China Bed, and at the old Greyhound Pit as the Spar Band. This seam crops out on the railway at Lowca Point and in Lowca Beck below Moresby Hall. The next, or *Cleator Moor Four Foot* seam, probably represents that known at Whitehaven as the *Preston Isle Yard Band*. The measures between these seams are usually clays and shales. Sandstones are locally more abundant above the *Cleator Six Foot* horizon, and may be seen capping the cliffs south of Parton.

Whitehaven Sandstone Series.—Mr. Eastwood finds that the Whitehaven Sandstone Series consists of sandstones and shales varying from purple and dull red to pale grey. Sandstones predominate in the lower part of the series, shales being thicker and more abundant at higher horizons which are characterised by the presence of thin bands of Spirorbis limestone. In the area surveyed by Mr. Eastwood the series has been proved to a thickness of 600 feet.

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The sandstones vary from fine flaggy beds to coarse grits with fragments of quartz up to the size of a pea; but usually the rock is a rough fairly coarse sandstone occurring in thick beds separated by thin irregular partings of shale. While no actual grains of felspar have been noted, the rock is characterised by abundant white specks that suggest the former presence of that mineral. As a rule mica is not common. Almost every exposure shows small cakes and blebs of red shale or mudstone incorporated with the sandstones, and sometimes so heavily charged with iron as to be mistaken for pebbles of hæmatite. These blebs vary from isolated patches to aggregates forming lenticular beds recalling the 'pellet rocks' of the Keele Beds of the Midlands, and are evidently of similar origin. Shale partings in one portion of a section may be ascribed to 'pellet rock,' but elsewhere may arise from local contemporaneous erosion.

The shales call for no special remark except for the occurrence in them of limestones. These vary in thickness from about two feet to lines of small nodules, and in character from hard porcellanous creamy limestone to calcareous sandy mudstone. *Spirorbis* has been detected in the former type alone. It is interesting to note that hæmatite replacing a bed of Spirorbis limestone was at one time worked at Millyeat near Frizington.

From the foregoing account it might be assumed that the Whitehaven Sandstone is at all times easily distinguishable from the Productive Measures, but this is not the case. It frequently happens that the normal colourings of the Whitehaven Series and the Productive Measures are reversed, especially where the latter are much broken. The question then arises as to how much, if any, of the red and purple colour of the Whitehaven Series is original and how much is due to staining from the Trias. The widespread nature of the colouring and the occasional repeated alternations of red and grey rocks suggest that much of the colour is original, though the presence of greenish and grey patches in one part of a section, and of very dark red and purple at another, points to some migration of colouring matter.

From the coast at Whitehaven to about two miles inland, the base of the Whitehaven Sandstone keeps approximately 500 feet above the Main Band Coal, and the junction seen on the beach near William Pit appears to be a passage from the Lower (or Productive) series to the Upper. It might be inferred that the Whitehaven Sandstone is conformable to the Productive Measures and that red rocks encountered closer to the Main Band are not Whitehaven Sandstone but stained Productive Measures. This has been disproved by mining operations beneath a large tract of Whitehaven Sandstone, that extends over Weddicar Rigg. The eastern workings from Walk Mill Colliery prove that the Main Band is about 300 feet below the surface. Unless there is a remarkable thinning of the measures between the Main Band and the base of the Whitehaven Sandstone (a point that has not been proved), it follows that the latter is unconformable, and cuts

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down rather rapidly into the Productive Measures, removing the upper coals one by one as it proceeds eastwards.

NEW RED SERIES

In the area west of the St. Bees–Whitehaven valley, viz., St. Bees Headland or Preston Isle, the rocks comprised under the above title consist of the following :—

	Thickness at Barrowmouth.
St. Bees Sandstone	200 ft.
Gypsiferous Shales and Marls ...	100 ,,
Magnesian Limestone	14 ,,
Breccia	6 ,,

UNCONFORMITY

Coal Measures (Whitehaven Sandstone).

This sequence, as exposed on the beach and in the cliffs at Barrowmouth, Saltom Bay, was described long ago by Sedgwick, Binney, Murchison and Harkness, who appear to have assigned the whole group to the Permian Series. On the Old Series Survey map the Magnesian Limestone and Breccia are shown as Permian and the Gypsiferous Shales as Trias.

As the rocks are followed south-eastward, however, into the Bigrigg and Cleator district, Mr. Smith finds that some remarkable changes take place that tend to throw doubts upon the latter correlation. At this stage it seems best to classify all the beds as 'New Red Series' and consider only the facts.

No great change takes place in the thickness or character of the three lower members up to a point near where they are last observed west of the St. Bees-Whitehaven valley, but when they reappear in Linethwaite Beck and Parkhouse Gill on the east side of the valley considerable changes have occurred. (1) The Breccia below the Magnesian Limestone has increased considerably in thickness. (2) The Limestone is reduced to two feet and finally disappears altogether. (3) Breccia of exactly the same type has developed in the overlying shales and marls, which contain layers, pockets and fine dustings of breccia material at still higher levels. (4) Gypsum and anhydrite are usually absent.

In the Egremont district and beyond the southern margin of the Whitehaven Sheet, we find that the lower parts of the St. Bees Sandstone contain layers of breccia material, and the sandstone rests directly upon thick breccias (with included sandy and shaly beds) which must represent the whole of the Gypsiferous Shales, Magnesian Limestone and Breccia of the Barrowmouth section, if not some of the St. Bees Sandstone also.

Not only is there a lateral passage of the lower beds into breccia, but each division, by including some beds of the types above or below, passes by intermediate and sometimes imperceptible stages into the next division. The whole series, in fact, presents a conformable sequence.

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This state of affairs was recognised by R. Russell, who, in writing to Topley[1] in 1888 states that " when we come to consider the stratigraphical condition of these beds, we find that they all pass gradually either horizontally or vertically, or in both directions, from one to the other. No natural division occurs amongst these Red Rocks."

In the southern district again, deep bore holes show a great thickness of almost shale-less sandstone, overlying the sandstones and shales typically developed in St. Bees Headland. These have been claimed by Prof. J. W. Gregory[2] to represent Kirklinton Sandstone. No definite boundary can be drawn, however, between the two divisions, for similar types of sandstone occur both above and within the lower (or St. Bees) shaly division. Thus we are confronted with the same conditions as in the Carlisle district (p. 44), where the St. Bees Sandstone passes into Kirklinton Sandstone. In the district under discussion, however, the difference between the two types is less marked, and they obviously arose from the same physical conditions.

The Breccia.—At Barrowmouth Mr. Smith finds that the Breccia rests upon a fairly even eroded platform of well-jointed Whitehaven Sandstone. Here and there the floor is irregular, and the breccia fills joints and cracks quite 3 ft. below the general surface of the platform : some ledges in the platform are underpacked. The platform, however, is not nearly so irregular as the wave-cut platform that is being formed by present marine action.

The Breccia dips S.W. at 5° and consists chiefly of a dark reddish-purple sandy or muddy deposit full of angular to subangular fragments, amongst which Carboniferous sandstones, liver-coloured quartzites and hæmatitised shales and mudstones are predominant. About 5 to 10 per cent. of the fragments consist of Carboniferous limestone and are in rounder forms and frequently dolomitised. Cherts also are present. The larger fragments of the Breccia are from 6 in. to 9 in. in length. Thin sandy layers and lines of small stones exhibit a well-marked bedding.

At the western end of Benhow Wood, N.E. of Demesne, the Breccia is 9 ft. thick and contains angular fragments of Carboniferous limestone up to one foot in size. In Linethwaite Beck (Parkhouse Gill) the Breccia beneath the Magnesian Limestone is red and of similar type, but has increased to over 30 ft. in thickness.

Breccia occurs also above the Magnesian Limestone, evidently developed in the Gypsiferous Shales and Marls, of which about 40 ft. may be here assigned to breccias. That immediately overlying the Limestone cannot be differentiated from certain beds below. The greater part of the Shale series now ascribed to the Breccia consists of soft red micaceous laminated sandstones,

[1] MSS. in possession of Geological Survey.

[2] 'A Deep Bore at Seascale in Cumberland,' *Geol. Mag.*, 1915, pp. 146-149.

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red shales and mudstones, occasionally nodular, containing here and there chips of marl and fragments of extraneous rocks. Farther to the south-east, near Parkhouse Farm, the lower breccia dipping west at about 15° averages 50 ft. in thickness, whilst the Magnesian Limestone is from 1 foot to 1 foot 6 in. thick, and the upper breccia is similar to the lower and about 100 ft. in thickness. Both the higher and lower breccias contain a large proportion of Carboniferous limestone.

Above the breccias, 80 ft. to 100 ft. of the beds must be ascribed to the Shale and Marl series beneath the main St. Bees Sandstone; they contain nests of fine breccia and bands of ripple-marked sandstone, thus having some of the characteristics of Breccia and some of St. Bees Sandstone. The offices of Parkhouse Mine are situated on the outcrop of the lower breccia, which rests upon the ' Millstone Grit ' exposed farther east in the Bigrigg (Pallaflat) railway-cutting (p. 55).

Instructive sections in the breccias mapped by Mr. Eastwood are found in Dub Beck, between Weddicar Hall and Millyeat, where the formation rests on the upper part of the Whitehaven Sandstone series, the actual junction being seen near the sharp bend of the stream by the weir. Unlike the section at Barrowmouth, this junction forms a regular plane, whether the underlying rock be sandstone or shale. The breccia at the base does not differ materially either in composition or size of fragments from that exposed for twenty feet above it, and consists of the usual assemblage of angular fragments of Skiddaw Slate, igneous rocks probably derived from the Borrowdale Series, and Carboniferous limestone, the last-named forming nearly 20 per cent. of the stones. The breccia contains at this point occasional large fragments of Whitehaven Sandstone. Although the constituents are not regularly arranged the rock occurs in a series of thick even posts.

Near Weddicar Hall the Breccia is cut off by a fault throwing in Coal Measures. It is next seen in the railway-cutting at Keekle Terrace, where it rests on Whitehaven Sandstone lower in the sequence than at Millyeat. Between Keekle Terrace and the Limestone inlier at Overend, the Breccia underlies St. Bees Sandstone, but its one outcrop is in the gully west of Keekle Bridge.

Northwards the Breccia rests on Whitehaven Sandstone in the Keekle at Walk Mill, where it is let in by trough faults against Bannock Band Rock on the north-east, and measures about the Yard Band horizon on the south-west. Near the latter fault the Breccia approaches the St. Bees type of rock. On Weddicar Rigg, eastwards of the Keekle, breccia is worked intermittently for road-gravel. It is much less consolidated than elsewhere; all the fragments are filmed with hæmatite and limestone is conspicuous by its absence.

The Magnesian Limestone.—This formation, as mapped at Barrowmouth by Mr. Smith, consists of a lower 8-ft. magnesian

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limestone occurring in posts up to 1 ft. 9 in. in thickness, succeeded by a 3-ft. belt of shales with thin limestones, which are overlain by 3 ft. or more of thin limestones and shales. These pass upwards into the Gypsiferous Shales and Marls, but the top of the section is obscured by landslides.

The lowest foot of limestone is flaggy and contains fragments of shale, sandstone, &c., like those in the underlying breccia, whilst scattered pellets occur quite 3 ft. above the base. Occasionally the limestone is crystalline; at other spots it is cavernous and rubbly, and contains layers of poorly preserved fossils, including *Pleurophorus costatus* (Brown), a well specialised form characteristic of the higher part of the Magnesian Limestone of Co. Durham, and widely distributed in the Zechstein of Germany and the Permian rocks of Russia.

Inland, an old quarry N.W. of Barrowmouth Farm exposes at one point about 2 ft. of limestone-breccia on 2 ft. of platy magnesian limestone dipping S.W. at 10°. In the centre of this breccia is a band of extraneous pebbles. These beds overlie about 10 ft. of more solid magnesian limestone. Both here and on the coast the limestone has thin layers of secondary gypsum on the joint-faces.

South-eastward Mr. Smith observed that the rock was exposed in road-sections and old quarries, usually dipping S.W. at about 10°. On the west side of the St. Bees road at Roskapark Wood, ¼ mile N.E. of Demesne, about 15 ft. of the limestone is seen; whilst on the east side of the road boulder-clay overlies 12 ft. of limestone on 9 ft. of breccia resting on purple Coal Measures sandstones and shales. Farther south-east the limestone is 16 ft. thick in Bellhouse Gill, where it is faulted against Coal Measures.

Gypsiferous Shales and Marls.—At Barrowmouth the Gypsiferous Shales and Marls aggregate about 100 ft. in thickness and pass upwards into the lower shaly division of the St. Bees Sandstone. The gypsum occurring here[1] was estimated by Binney to be 29 ft. thick, the largest bed measuring 15 ft. It is white and saccharoidal, but is frequently stained pink or mixed with reddish marl. It was mined at intervals between 1863 and 1908.

Beds above the gypsum zone are exposed a few dozen yards S.W. of Barrowmouth Farm and consist of micaceous laminated shales, and blocky sandy marls with fine dustings of extraneous materials, forecasting the oncoming of breccias at this horizon farther inland.

In Roskapark Wood, north of Demesne, the beds dip S.S.W. at from 6° to 8°, and consist of blocky and nodular marls and shales with bands of thin grey magnesian limestone in places. The marls are occasionally spotted green. In Bellhouse Gill,

[1] 'Special Reports on the Mineral Resources of Great Britain, vol. iii., Gypsum and Anhydrite' (*Mem. Geol. Surv.*), ed. 2, 1918, p. 15.

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over 1 mile S.E. of Barrowmouth, the series contains thin beds of red sandstone in thin sandy and blocky micaceous flags and marls with manganese staining. Some bands are greenish. In this area the beds are probably over 100 ft. thick, and give rise to a broad stretch of ground of low relief between Roskapark Wood and Sandwith.

In Parkhouse Gill the division contains beds of red sandstone as well as beds with dustings of breccia; true breccias are developed thickly in the lower parts.

No gypsum occurs at the outcrop S.E. of Barrowmouth, but it has been proved in deep borings at points about a mile S. of Bell House and at Gutterfoot, St. Bees; hence it is probable that the gypsiferous phase occurs at intervals beneath the whole of the St. Bees Headland.

St. Bees Sandstone.—In the area mapped by Mr. Smith. unrivalled sections of St. Bees Sandstone occur in the cliffs of St. Bees Head between Barrowmouth and St. Bees, and in the numerous old quarries scattered along the cliff top. The beds exposed in McKay's quarry, about half a mile S.W. of Barrowmouth Farm, are from 220 ft. to 300 ft. above the base of the group, and consist of 77 ft. 6 in. of red stone quarried for building and occurring in large posts, with some pale greenish bands. Very little shale occurs here. The top 9 ft. of the rock, beneath the soil, is micaceous sandstone appearing as an irregular flaggy rock (' rammel '). This is characteristic of all exposures of St. Bees Sandstone and must be a result of weathering.

The pale greenish layers are used as flags, and have been employed in George Washington's House in the U.S.A.

The sandstone beneath this quarry, exposed between it and Barrowmouth Farm, is interstratified with more shaly layers, and some of the sandstones exhibit the contortions and ' ball-like ' structures typical of alternations of sandstone and shale that have suffered readjustments before consolidation.

The sandstones are fine-grained, laminated and false-bedded, micaceous and occasionally ripple-marked, and frequently contain pellets of marl.

As far south as the Lighthouse the dip is westward, or south-westward, at from 6° to 12°; but from there to Fleswick Bay, where a fine section is accessible, the dip swings round to a southerly direction. From Fleswick to St. Bees the dip is S.S.W. at from 10° to 12°.

Whilst the highest beds exposed in the headland contain some chocolate shales, they are neither abundant nor striking. The Gutterfoot boring at St. Bees proved that (allowing for the height of the headland) from 1,200 ft. to 1,300 ft. of the sandstone series is present above the true Gypsiferous Shales in this area.

Mr. Eastwood reports that the St. Bees Sandstone, although easily distinguishable, makes little show in the tract between Whitehaven and Frizington. It occurs between the fault

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limiting the limestone inlier of Hensingham and Keekle Terrace. Though masked by drift, it is occasionally exposed in stream sections. Near Frizington it crops out in the higher part of the Rheda estate and has supplied the bulk of the building material for the Hall. A large quarry, now an ornamental pond, near the east lodge of Rheda, provides a typical section of the sandstone, here dipping south-west at 17°.

GLACIAL

The Glacial deposits in this area consist of boulder-clays and associated sands and gravels, that together mask a considerable portion of the country, but not sufficiently in all cases to disguise the general trend of the rock formations. They were due to both Lake District, or local ice, and ice travelling coast-wise from the Criffel district of S.W. Scotland.

Interesting phenomena that occurred at the margin of the two ice-sheets at the mouth of Ennerdale are described in detail in Appendix I, pp. 118–128.

Although drift conceals much of the solid geology in the country mapped by Mr. Eastwood, its extent is not nearly so great as indicated upon the old map. It presents no remarkable character, being for the most part reddish or greyish boulder-clay with occasional sandy patches and, more rarely, small masses of gravel such as may be seen near Parton.

In the area mapped by Mr. Smith the deposits consist largely of boulder-clay, the product chiefly of the Irish Sea ice-sheet.

The sandstone of St. Bees Headland proved to be mostly free from drift, with the exception of a scattering of small erratics and larger boulders and a few patches of clay that hold up surface waters. At Fleswick Bay, however, and at Rottington Common and Sandwith Newton, typical tough boulder-clay of considerable thickness is present.

The floor and flanks of the St. Bees–Whitehaven valley, as far south, at least, as the gap in the St. Bees Sandstone escarpment, are mostly drift-covered; whilst large spreads occur in the Cleator Moor–Bigrigg area.

A dissected fan-shaped spread of gravel, with the handle of the fan pointing towards Moor Row Station, caps the boulder-clay on the east side of the St. Bees–Whitehaven valley, between Hensingham and Bigrigg. The outspread fan is about 1 mile in width, and in places the deposit is quite 30 ft. in thickness.

The most striking development of glacial deposits, however, occurs on the sea-coast at St. Bees, where a lower purplish boulder-clay is overlain by a thick series of sands and gravels that form the hummocky ground at the mouth of the valley.

Here and there the gravels are capped by either one or two beds of peat with associated sands and loams; and at one point a pale red upper boulder-clay was discovered resting upon disturbed and contorted peat beds, the thrust being from seaward,

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thus seeming to show that the peats are interglacial. They are now being studied by Miss M. E. J. Chandler.

The lower boulder-clay rests upon the St. Bees Sandstone at the south end of the headland, its surface, at its highest point, where the clay is overlapped by gravels, rising to over 100 ft. above sea-level. From this point it sinks eastward to beach-level, allowing the Rottington Beck to breach the gravels. South of the old Seacote Hotel the clay rises from beneath the beach to a height of, roughly, 80 ft. to 90 ft., and sinks again below beach-level near Sea Mill, where the Pow Beck, draining the St. Bees valley, enters the sea. A little south of this point the clay rises into the cliff, exhibiting a fine section capped by gravels.

The gravels extend for about three-quarters of a mile inland along the course of the Rottington Beck; and beyond St. Bees itself, upon the east side of the main valley, to a point nearly 7 miles from the sea.

A few patches only of upper boulder-clay were found, but quite sufficient to prove the former existence of a more extensive sheet. This occurrence of hummocky Irish Sea drift, overlying boulder-clay in the mouth of a valley, succeeded by a second clay due to a restricted re-advance of the ice-sheet, tallies with the phenomena observed at and near the mouth of the Whicham valley farther south[1]. Probably also an extra-morainic lake was held up behind the St. Bees drift.

It is hoped that the flora of the peats, when worked out, will prove whether the 'middle glacial sands and gravels' of this coast-line were the result of a great amelioration of the climate.

5. Northumberland and Durham District

Headquarters: Newcastle-on-Tyne.

R. G. Carruthers, District Geologist.
C. H. Dinham, B.A. - }
G. A. Burnett, B.Sc. - } Geologists.
A. Fowler, M.A., B.Sc. }
F. Marsden, M.Sc. - }

In pursuance of the policy outlined in last year's "Summary of Progress" the revision of the Lower Carboniferous tract from Berwick-on-Tweed southwards has been continued. Mr. Fowler worked in the triangle Berwick–Norham–Goswick (Sheets 1 and 2), and Mr. Marsden took the Coldstream–Etal area (Sheet 3). The large area in Sheet 4 was divided between Mr. Carruthers (Holy Island and Lowick), Mr. Dinham (Belford and Bamburgh) and Mr. Burnett (Beadnell, Lucker and Chatton district).

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[1] 'The Glaciation of the Black Coombe District (Cumberland)' *Quart. Journ. Geol. Soc.*, vol. lxviii., 1912, pp. 441, 445.

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The general rock sequence amounts to at least 5,000 ft., distributed as follows :—

	Ft.
Lickar Coal Group - - - - -	200
Limestone Group - - - - - -	1,500
Scremerston Coal Group - - -	1,000
Fells Sandstone - - - - - -	600
Cementstone or Tuedian Group - -	2,000–3,000
Kelso Lavas (local).	
Cheviot volcanics (Old Red Sandstone).	

The region is one of low relief, with an extensive drift covering, and there is much local complexity of structure not easily deciphered : there are notable sections of the Limestone Group on the coast round Berwick and at Beadnell, while the Cementstone Group is well seen along the bank of the Tweed and Till below Coldstream and Etal. Half-a-century ago many limestone quarries and small coal-pits were at work, but except for Scremerston Colliery, they have long been abandoned. It is doubtful if limestone will ever be wrought again on any considerable scale, the surface cover being too heavy. As to the coals, little is left of the Lickar seams, while the few that are workable in the Limestone Group are of no great account : concerning the Scremerston Coals one can be more optimistic, for there are extensive reserves still intact at shallow depths; the seams are numerous, and though generally soft and dirty should be suitable for power-gas and by-product purposes.

The original Survey field-maps were executed with remarkable care by Mr. W. Gunn between the years 1870–1880 : the lines then drawn have in the main been proved to hold good, although a few alterations and several additions of some moment have been made, chiefly by the use of palæontological data. Particular attention has been paid to the indication of promising areas of the Scremerston Coals, and to discover characteristic features, or "marks," of service in recognising definite horizons when boring through the supervening Limestone Group.

Old Red Sandstone.—Mr. Marsden reports that in the area of Cheviot lavas N. of the Bowmont Water, it has been impossible to map out individual flows owing to the uniformity of rock-type : in general, the andesites south-west of Howtel often show black mica, and the rock is distinctly redder than in the country to the north. The lavas are much decomposed at their junctions with the Cementstone Group near Milfield, and evidently there was much subaerial denudation before the Carboniferous rocks were deposited. The absence at Milfield of both the Kelso Lavas and the Carham Limestone is no doubt due to overlap on to the Cheviot massif.

Cementstone Group.—It has long been known that in the excellent sections along the valleys of the Tweed and Till, these strata are of a pronounced estuarine character, *Naiadites*, ento-

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mostraca, and *Spirorbis*, along with plant debris, being particularly abundant; in this respect they differ from the Liddesdale exposures on the west of the Border, where purely marine fossils are not uncommon. Mr. Marsden, however, has noticed *Syringopora* in the Tweed section north of Brownridge, on the east bank of the Till opposite Old Heaton, and again at Broombridge Dean, east of Kimmerston. In the Cornhill district, from material collected by Mr. Marsden, Dr. Kidston has been able to identify *Lepidodendron nathorsti* and *Adiantites antiquus* from shales in the Willow Burn, ½ mile S.W. of West Learmouth, and there is hope that with further collecting considerable additions may be made to our scanty knowledge of the plant life in these rocks.

Scremerston Coal Group.—A complete record of this series, as developed around Scremerston itself, was obtained in 1914–15 from three diamond bores put down for the Director of Greenwich Hospital. The cores, which were in a very complete state, were examined at the time by Mr. Carruthers; pending a complete account of this matter it may be noted that the whole group from the Dun Limestone down to the top of the Fells Sandstone, proved to be some 1,080 ft. thick: there were at least 10 coal seams (some over 2 ft. thick), the best of these being the Scremerston Main Coal, as follows:—

Section of the Main Coal in No. 1 Bore, Scremerston.

	Ft.	in.
Roof. Soft grey shale	–	–
Coal	2	6
Hard Grey shale		8
Sandstone, rib, hard, and with entomostraca at the top	1	1
Foul Coal		10
Dark grey limy ironstone, with pyritised entomostraca and gasteropods	1	3
Coal	2	6
Pavement. Sandy shale and fireclay.		

The only fossils in the Scremerston Group, either in these borings or elsewhere, as noted by previous observers, are of estuarine or freshwater character (*Naiadites*, entomostraca, *Spirorbis*, small gasteropods, and comminuted plant debris). Mr. Marsden, however, has noticed in Duddo Mill Burn, near Etal Colliery, a 9-in. limestone with crinoidal debris, about 50 feet below the Fawcet Coal; 5 ft. below this is a 10-in. coal, interbedded with which are shaly partings yielding *Fenestella*, and small crinoid ossicles along with *Spirorbis* and *Naiadites*. North of this exposure the limestone is again visible in the old clay pit at Duddo Tile Works.

The Scremerston Coals undoubtedly improve in a northern direction both in thickness and quality. It is quite possible that they may be in good state below the covering fringe of higher strata along the coast north of Berwick, where Mr. Fowler has been able to confirm Mr. Gunn's correlation of the Lamberton or Marshall Meadows Limestone with the Dun, *i.e.*, the limestone immediately overlying the Coal Group. The strata lie practically

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flat hereabouts, but most of the seams would have to be wrought undersea.

South of Belford, Mr. Burnett has examined the well-marked anticline of the Scremerston Group, south-west of Twizell House: the Fawcet Coal has been wrought on either side of the fold, but the Main Coal and lower seams do not outcrop, though they must be very close to the surface. This unproved area should be worth attention in the future, and also the ground E. of Commonflat, where strata below the Dun Limestone are seen in the Priest Burn at least as far east as the main road to Alnwick.

Limestone Group.—Within this group there are, in North Northumberland, at least 16 distinct bands of crinoidal limestone, ranging from the Great or Dryburn Limestone down to the Dun and distributed through some 1,500 ft. of strata. The sequence has been detailed by Mr. Gunn in various publications, especially in the Memoir on 'The Geology of the Coast south of Berwick-on-Tweed.' Although the series is equivalent to the Lower Limestones, together with at least the upper half of the Oil-shale Group of Scotland, as a matter of fact only one oil-shale of the Lothian type is known, that of the Doubster Burn, near Scremerston. The individual limestone bands, though thoroughly marine, differ somewhat from the Scottish ones in that the overlying shales are generally poor in fossils, and the limestones themselves often rest directly on the coal beneath, without the intervention of an 'estuarine' shale; quite commonly indeed, there is an actual interbedding of crinoidal limestone or shale with coal, which in such cases may be, in part at least, a true drifted deposit.

The fine shore sections at Spital, south of Berwick, have been measured by Mr. Fowler, and those at Beadnell by Mr. Burnett; they have proved of great value as standards of reference. Although fully 18 miles apart, these two sections agree remarkably well, the 13 limestones between the Dryburn and Oxford at Beadnell all reappearing at Spital with but little change. Using the Spital section for the interpretation of the coast section north of the Tweed, Mr. Fowler has been able to identify both the Doubster Oil-Shale and the Oxford Limestone at Calot Shad, south of the breakwater; again, in the synclines farther north at Bucket Rocks and Greens Haven, he has recognised the Eelwell Limestone, 27 ft. thick; and north of the Greens Haven fault the Oxford Limestone, 14 ft. thick. These readings are all new, for although the sections are easily accessible, little work seems to have been done on them.

On Holy Island, Mr. Carruthers finds that the limestone seen on the shore south of the Cathedral ruins, previously mapped and described as the Lowdean or Sandbanks Limestone, should be referred to the Acre. In North Northumberland, the shale immediately overlying the Acre Limestone is of a highly characteristic nature; not only are the fossils remarkable for their variety and good preservation, but certain of them (a small

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narrow variety of *Cyathaxonia cornu* and a new species of *Caninia* akin to *C. cornucopiæ*, are restricted to this horizon. It is worthy of remark that precisely the same assemblage is found in Scotland above the middle Skateraw Limestone at Dunbar, whose identity with the Acre can be inferred from Mr. Gunn's table of correlations.[1] The Holy Island exposure of the Acre shale, seen immediately east of the lifeboat house south of the Cathedral ruins, is complete and typical.

On the mainland, opposite Holy Island, an important correction has been made in the reading of the ground round Fenwick. A limestone formerly wrought at the steading east of the Berwick main road was referred to in the Memoir on the Belford District as 'probably one of the higher limestones (Eelwell or a higher one).' There can be little doubt, however, that it is in reality the Dun Limestone, a thousand feet or more below the Eelwell; not only is the general character strongly reminiscent of the Dun, but the shale above has yielded a large finely-ribbed *Productus*, *Zaphrentis lawstonensis*, and a polyzoan identified by Dr. Lee as *Tabulipora howsei*, all these being fossils characteristic of the Dun position. The limestone at Fenwick Granary, north of this, though mapped as the Watchlaw, is more probably the Woodend, with which it is in agreement lithologically, and also in the presence of a coal seam a few feet above. A large fault running alongside the Berwick road, down south-east, must separate this tract from the higher strata seen to the west. Since the Scremerston Coal Group directly underlies the Dun Limestone, these alterations in the mapping have a distinct economic value.

Some modification has been made near East Kyloe, where the limestone crossing the stream west of the hamlet is in the Dun, not the Woodend, position.

In the Belford–Bamburgh area, revised by Mr. Dinham, there is a great deal of drift, and the few rock sections both on the coast and inland, are of a fragmentary nature. In the search for characteristic features amongst the limestones, attention was paid to certain porcellanous-looking haloes, surrounding fragments of fossils, which were previously recorded by Professor Garwood from the Oxford Limestone[2] and later ascribed by him to *Girvanella*.[3] In the Belford district, and indeed over the whole of North Northumberland, these *Girvanella* nodules are a special character of the Oxford position; the only other limestone in which they are at all conspicuous is the Dun, where, however, they are decidedly less numerous. As an example of their use in the interpretation of doubtful ground, the limestone of Elford Quarry can now be definitely assigned to the Oxford.

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[1] W. Gunn, 'Notes on the correlation of the Lower Carboniferous Rocks of England and Scotland.' *Geol. Mag.*, 1898, p. 348. The correlation is given in the text (p. 347), where it is ascribed to Mr. James Bennie.

[2] In Bateson's 'History of Northumberland,' vol. i., 1893.

[3] *Quart. Journ. Geol. Soc.*, vol. lxviii., 1912, p. 547.

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The shales overlying a limestone in Budle Bay, west of Bamburgh, have long been known for their abundance of *Posidonomya becheri*. This lamellibranch is rarely found in English Carboniferous Limestone strata though common in the over-lying shale series (Pendlesides). It had been recorded in Northumberland from one or two other limestones of doubtful horizon, and is so easily recognised that an effort was made to test its value as a stratigraphical index. The inquiry showed that the *becheri* shales of Budle, Easingtongrange Mill and Glororum quarries, probably belong to the 3rd limestone above the Oxford. Mr. Burnett has also obtained the shell from the same horizon on the Beadnell coast, and in the Long Burn at Tugganmill and at Fleetham. This, however, is by no means the only level at which *P. becheri* was found; it was noticed in fair abundance in a similar tough mudstone at Greenhill Rocks, Bamburgh, overlying the first limestone below the Oxford; and rare specimens were collected from shales over the Oxford Limestone itself, in the quarries north-west of Elford and west of Easington Demesne. These occurrences discount the use of the shell as a stratigraphical guide, though it may perhaps have some local value.

In the Belford district and to the south of Mounthooly, Lowick, a new marine horizon was noticed above the Upper Howgate Coal.

The quartz-dolerite intrusion known as the Whin Sill is prominent in the Belford country, where it forms a stepped series of escarpments, regarded by Mr. Gunn as separate intrusions at distinct stratigraphical horizons. There is considerable evidence that such appearances are often better ascribed to abrupt transgressions of a single sill, in much the same manner as the quartz-dolerite sheets behave in the Central Valley of Scotland.

In the Beadnell-Ellingham district Mr. Burnett reports that while little change is needed in the reading of the limestones, some modifications have been made in the fault lines; much of the structure of the ground is obscure, and more work is required to clear up doubtful points. Mr. Gunn considered that the coals wrought long ago at Coldrife Colliery were most probably the Lickar seams; there is, however, good reason to think that they represent the Howgate Coals, lying between the Oxford and Woodend Limestones.

Lickar Coals.—The two small synclines of this series at Lickar and Berrington have long been exhausted. Further areas may exist in the low ground W. of Goswick, but the coals do not reappear to the south until we reach Brunton, south of Ellingham; where, in the stream above the railway bridge, Mr. Burnett has noticed abundant fragments of a striped blackband ironstone practically *in situ*. This may perhaps be the equivalent of the so-called 'oil-shale' at Berrington and Lickar, which is a micaceous 'parrot shale,' such as is usually associated with blackband ironstones elsewhere.

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Glacial Deposits.—There are two kinds of boulder clay in North Northumberland, one a stiff dark clay, crowded with local rocks, the other a red clay with much finer material, and of more distant origin. The relationship of these clays to one another is well seen in the low cliffs at the south end of Holy Island, particularly west of the village. The dark clay lies at the bottom and is a true ground moraine, packed with local rock debris. Some of the sandstone lenticles, though only a foot or so thick, are as much as 20 yards long. They seem to have been frozen in and dragged along the sole of the ice-sheet, since they are horizontally disposed, and, though unbroken themselves, rest among highly contorted rock debris. The overlying red clay shows no such signs of movement, and between the two clays is a parting of sand and gravel, quite undisturbed. Similar sections are to be seen on the east side of the island opposite Broad Stones.

These phenomena seem to be strictly comparable with those observed by Mr. Lamplugh in 1910,[1] where the conjunction of two dissimilar clays was shown to be due to the melting of a single ice-sheet, resulting in a quiet setting-down of the included and superficial debris on to the ground moraine. This interpretation of the Holy Island sections may apply to much of the boulder clay areas of North Northumberland, where the two clays are known and are accompanied by thin sheets of sand and gravel whose origin has hitherto been somewhat obscure.

The investigation of the so-called 'kames' at Wark and Pallinburn in the Tweed Valley, and at Bradford and Lucker south-east of Belford,[2] is still proceeding, as is that on the 'glacial lake' in Glendale and the Till Valley.

Mr. Marsden has been able to show that the small 'inliers' of Kelso Lavas at Wark West Common and east of Sunnylaws are probably large erratics, or accumulations of erratics, carried eastward from the main outcrop above Carham.

(B)—SCOTLAND

Coalfield Revision

1. Ayrshire Coalfield

E. B. Bailey, M.C., B.A., District Geologist.
E. M. Anderson, M.A., B.Sc.
J. E. Richey, M.C., B.A.
V. A. Eyles, B.Sc.
John B. Simpson, B.Sc. } Geologists.

Mr. Anderson and Mr. Richey were employed in North Ayrshire, in one-inch map Sheet 22. They made substantial progress

[1] G. W. Lamplugh, *Proc. Yorks. Geol. Soc.*, vol. xvii., pt. iii., 1911, pp. 237—8.

[2] Recently dealt with by Professor Gregory in a paper on 'The English Eskers,' *Geol. Mag.*, Jan. 1922, p. 25.

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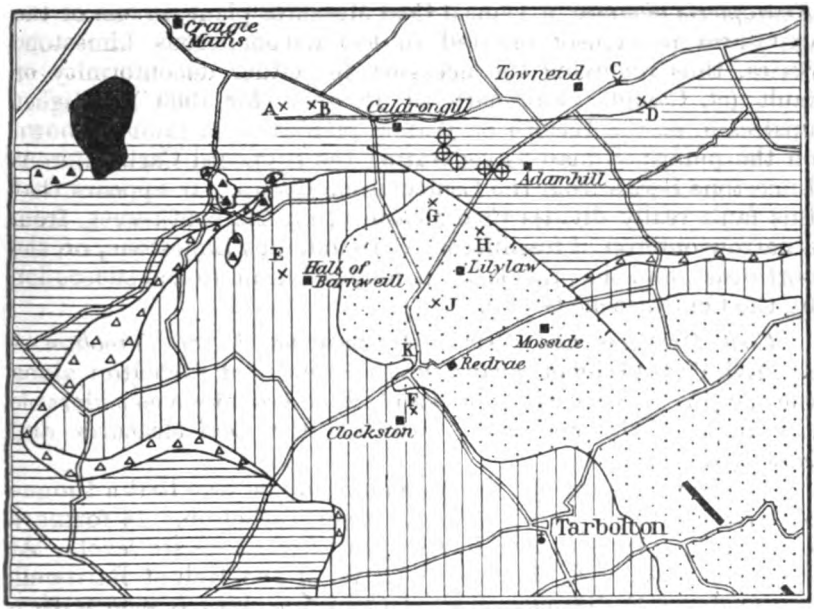
in matters of detail in regard to all divisions of the Carboniferous, from the Clyde lavas to Coal Measures inclusive. Mr. Eyles and Mr. Simpson started the revision of Central Ayrshire, on the junction of Sheets 14 and 22.

Millstone Grit Volcanic Zone, N. of Adamhill.—On the published one-inch map Sheet 22 'trap-tuff' is shown between the Coal Measures and Carboniferous Limestone Series in a roadside stream exposure east of Townend marked C on Fig. 2. The rocks consist of rotted olivine-basalt and bauxitic clay, and it has been recognised for some years past that they represent the top of the Millstone Grit volcanic group, including some



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Bedded Ash
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Basic Intrusions
Ash Necks
Barren Red & Productive Coal Measures
CARBONIFEROUS
Old Coal Pit

Scale of Miles
0 ¼ ½ ¾ 1 2

FIG. 2.—*Geological Map of the Tarbolton District.*

Ayrshire Bauxitic Clay. Mr. Eyles has found further exposures of rotted olivine-basalt at D, 375 yds. down-stream from C; and at A, in a small burn 200 yds. south of the road between Caldrongill and Craigie Mains. He has also met with volcanic

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mud at B, in another burn 200 yds. east of A. The exposure at D, and with less certainty those at A and B, are here referred to the Millstone Grit volcanic group, and a tentative line for the base of the Coal Measures is drawn accordingly on Fig. 2.

From the evidence available the bauxitic clay is very ferruginous and of poor quality.

Coal Measures and Carboniferous Limestone, N.W. of Sorn.—In Sheet 14, 2 miles north-west of Sorn, Barren Red Coal Measures are mapped unconformably lying on some part of the Carboniferous Limestone Series. In the Burn o' Need, a tributary entering the River Ayr at Catrine, Mr. Simpson has found *Neuropteris gigantea*, a typical Coal Measures plant, in one of the exposures previously referred to the Carboniferous Limestone Series, thus removing the necessity for either unconformity or fault (*cf.* Clough, 'Summary of Progress for 1909'). Higher upstream, at the Wealth of Waters plantation, a fault is shown on the published map as separating the supposed Carboniferous Limestone Series from the Cementstone Group. It appears that this fault really divides Coal Measures, on the south-west, from a narrow outcrop of fossiliferous Carboniferous Limestone, on the north-east, and that this latter is followed in unbroken succession by the Cementstone Group.

Coal Measures and New Red Sandstone, N. of Tarbolton.—Mr. Eyles' re-survey of the district to the north of Tarbolton, along the margin of one-inch Sheets 14 and 22, necessitates a considerable alteration of the boundary separating the Coal Measures and New Red Sandstone.

On the accompanying sketch map it will be seen that a tongue of lavas stretches west and north from Tarbolton. It forms a ridge varying from four to five hundred feet above sea-level. At a quarry marked E, 300 yds. W.N.W. of the Hall of Barnwell, and again at F, 100 yds. N.E. of Clockston, lava is seen with a gentle easterly dip; and, in fact, the eastern side of the ridge is shown by these exposures to approximate to a dip-slope. This, in itself, is a contradiction of the old reading, for, whereas the east face of the ridge was previously interpreted as a dip-slope as far as Clockston, it was treated as an escarpment in the neighbourhood of the Hall of Barnwell.

The area in which alteration is involved lies north and north-east of Redrae. Formerly the lava outcrop, shown on Fig. 2 as terminating east of Mosside, was continued in a straight course through ground without exposures, to join the Tarbolton outcrop at Redrae; and the sandstone exposures at G, H, J and K were mapped as Barren Red Coal Measures. These sandstones, however, with their orange-red colour and the wind-rounding of their larger grains, exactly resemble the New Red Sandstone and are totally unlike the Barren Red Coal Measures. Accordingly they are shown in Fig. 2 as continuous with the New Red Sandstone of the Mauchline basin, and as overlying the lavas which, at the Hall of Barnwell, are clearly seen to dip towards

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them. Their north-east boundary is not exposed, but must be a fault. On this interpretation of the structure the depth to coal round Lilylaw is increased to the extent of the thickness of the New Red Sandstone and lavas of this district.

New Red Lavas and Sandstone, Mauchline.—Mr. Simpson describes the lavas which underlie the sandstones and rest on the Barren Red Beds of the Coal Measures as fine-grained micro-porphyritic olivine basalts with a fair amount of lithological variation. A good section is exposed on the R. Ayr, between Catrine Holm and Howford Bridge. The outcrop is made up of many thin lava flows, which usually have well-marked slaggy upper portions. At several points small intercalations of sandstone occur with large rounded grains exactly similar to the overlying New Red Sandstone.

The last phase of the volcanic episode was marked by the outpouring of tuff, very well seen in the R. Ayr, immediately below the Howford Bridge. It is here seen that the upper portion of the tuff contains numbers of rounded sand grains about the size of millet seed, which become more numerous towards the top, where thin beds of sandstone are interleaved with tuff. Isolated patches of tuff occur in the first few feet of the New Red Sandstone, and one lenticular patch was noticed at least thirty feet above the unbroken top of the tuff proper.

On the Mauchline–Catrine road, ¾ mile west of Mauchline, new exposures of lava have been noted which necessitate the drawing of the boundary between the lavas and the Barren Red beds 300 yds. farther east than is shown on the old map.

Half a mile to the east of the farm of Brigland in the Barren Red beds, and about three-quarters of a mile N.E. of the lava scarp, an outcrop of basalt similar to the Mauchline lavas is exposed in the form of a circular knoll. No boundary is visible, but it appears to be a plug in a neck, several of which are known outside the main lava outcrop.

Mr. Simpson has found that locally the New Red Sandstone of Mauchline is cut by fairly numerous large basic igneous dykes, few of which have been previously recorded. Within about three miles west and two miles south of Mauchline Station there are some eight dykes exposed running in various directions between N.N.W. and W. 20° S. For comparison with the E. and W. quartz-dolerites of the Forth Basin, two examples with an E. and W. trend were sliced, and were found to be olivine-dolerites of Tertiary type.

Glacial.—The common occurrence of shelly clays, not assignable to late-Glacial or post-Glacial raised-beaches, is a feature of the geology of Central Ayrshire that has attracted considerable attention in the past.[1] Additional instances have been met

[1] *Cf.* John Smith, in 'The Drift or Glacial Formation of the Clyde Drainage Area'—Fauna, Flora and Geology of the Clyde Area (Handbook for British Association, Glasgow), 1901, p. 526.

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with during the past season by Mr. Eyles, who records a particularly good exposure in a burn 100 yds. north of Alton Lodge, on the main road midway between Ayr and Mauchline. Here shelly clay is discontinuously exposed over a total length of 350 yds., with a breadth of at least 50 yds., and at elevations from 250 to 300 ft. above O.D.

The clay is very stiff and fine-grained. It contains no boulders and only occasional small pebbles, not always of local origin. It is usually pale greenish grey, but in places blue-black, weathering brown. It shows distinct stratification in its upper layers, and is certainly an aqueous deposit.

The shells are mainly bivalves. They were kindly determined by Dr. James Ritchie of the Royal Scottish Museum, who found that they represent an arctic marine association.

The larger bivalves are always present as fragments, and sometimes broken pieces of a single valve are found in contact as if crushing had occurred during a disturbance of the containing clay. In other cases the fragments are isolated. The smaller shells are often perfectly preserved, retaining the epidermis, and in one or two cases both valves of a bivalve have been found together. The attitude of the shells in no case suggests that they were alive while the clay was being deposited.

Red boulder-clay occurs in the neighbourhood, and almost certainly overlies the shelly clay.

It must not be thought, however, that the shelly clays of Central Ayrshire are usually aqueous deposits. More often they are boulder-clays. Mr. Simpson has supplemented previous records from the Sorn and Ochiltree district by finding shell fragments in practically every exposure of Boulder Clay in the Bogend Burn of Catrine from 300 to 400 ft. above O.D. At one place, about 150 yds. upstream from where the railway crosses the burn, blue-grey silt is seen, about 330 ft. above O.D., overlain by boulder-clay. The silt is very rich in shell fragments lying at all angles, and is itself unbedded so far as can be seen in the small available exposure.

As bearing upon the possible source of the shells, it is interesting to note that Mr. Simpson has at one point found evidence suggestive of glacial carry from the west or south-west. In a stream-section through boulder-clay north of Auchmillanhill (N.E. of Mauchline), striated boulders are exposed which seem to have been derived from the lava group at the base of the New Red Sandstone to the west.

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2. Muirkirk and Lesmahagow, Stirlingshire, and Clackmannanshire

Muirkirk District

M. Macgregor, M.A., B.Sc., District Geologist.
G. V. Wilson, B.Sc.
H. H. Read, M.Sc., A.R.C.Sc.
D. Haldane, B.Sc.
G. Ross, B.Sc. } Geologists.

Mr. Wilson began the revision of the Glenbuck–Muirkirk area. Most of the field work was carried on among the older rocks north of the fault which forms the northern margin of the coalfield. This fault is probably a continuation of the fracture which extends south-westwards from Cronberry through Old Cumnock to the coast near Girvan.

Pre-Carboniferous Rocks.—The lowest members consist of Silurian shales and greywackes overlain in conformable succession by red, purple, and buff-coloured sandstones and marls of Downtonian age. The general dip of these rocks is to the north-west at angles varying from 20 to 70 degrees; locally the dip changes to the south-east, while, at the head of the Ponesk Burn, flat or rolling strata occur. The Upper Old Red Sandstone rocks are best developed near Middlefield. They have a total thickness of 500 to 600 feet, and consist of variegated sandstones and marls, showing purple, greenish, and yellow tints, with associated beds of cornstone. These latter may reach 20 or 30 feet in thickness and were formerly worked on an extensive scale at Middlefield quarries. The unconformable junction at the base of this series is seen in the Harwood and Burnfoot burns, where the Upper Old Red dips southwards off the underlying Downtonian. Farther east the dip changes to west, and where the unconformity is next exposed, on the south side of the Greenock Water, the underlying rocks are of Silurian age and the Upper Old Red Sandstone is dipping north-west.

Calciferous Sandstone Series.—In the centre of the basin of Old Red Sandstone rocks, the axis of which coincides roughly with the course of the Greenock Water, a good development of the Cementstone Group is found. Numerous exposures of soft grey marly fakes with occasional bands of cementstone are to be seen in the Harwood, Burnfoot and Mossy burns.

Igneous Rocks.—The main igneous rock of the district is the large intrusion of porphyritic felsite which extends along the northern margin of the boundary fault for a distance of several miles. This intrusion is later than the Old Red and most probably earlier than the Carboniferous Limestone.

A few small vents probably of Permian age occur, consisting of very basic and greatly decomposed tuff-like materials with large crystals of hornblende and biotite.

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Several north-west dykes of Tertiary type were noted. At a quarry at the side of the abandoned railway near Pauper Craigs an excellent example of one of these is seen cutting through the material of a volcanic vent.

Pleistocene and Recent.—The various stages in the retreat of the ice westwards down the valley of the Greenock Water are well illustrated in the country between the Dippal Burn and Glenbuck. It is clear from the topography that the great gorge of the Ponesk Burn is a late-Glacial feature, and that prior to its excavation the water flowed almost due westwards to join the Greenock Water near Blackside. The phenomena of retreat manifest themselves in a remarkable series of marginal and overflow channels, most of which except for insignificant streams are now practically dry. No. 1, the highest so far noted, has its intake on the divide between the headwaters of the Dippal and Patrick burns, and runs for over half-a-mile along the south-west shoulder of Priesthill Height at about the 1,300-foot level. On the south slopes of Starpet Rig again occurs a well-marked succession of marginal channels; three of these (Nos. 2, 3, and 4 of Fig. 3) are each about half-a-mile long and two of them

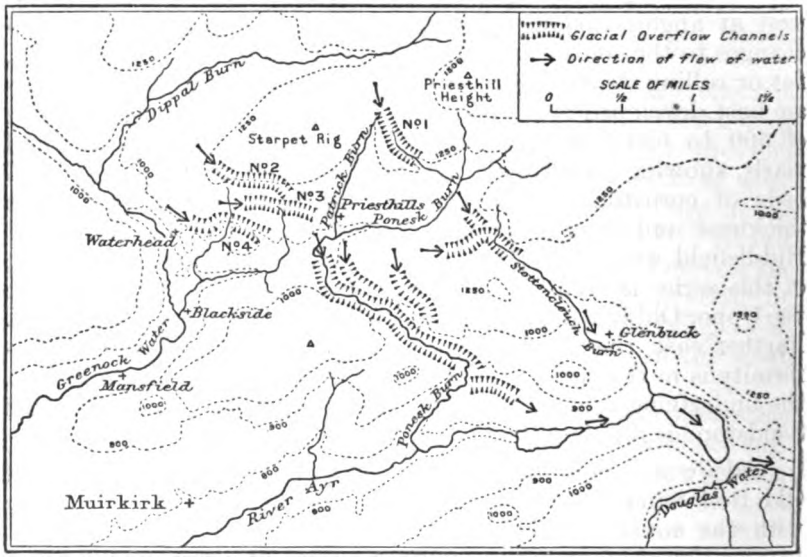

FIG. 3.—*Map showing Glacial Overflow Channels near Muirkirk.*

attain a depth of 100 feet or more. The intake of No. 2 lies at an elevation of about 1,275 feet. All these appear to have debouched into temporary glacial lakes held up along the front of the ice which blocked the Greenock valley and in the early stages at least also filled the Priesthills hollow. The drainage from these escaped in all cases south-eastwards into the Douglas valley by a well-defined series of overflow channels. Thus the waters of Nos. 1 and 2 marginal channels found outlets into the present Stottoncleuch Burn by two overflows cut at slightly

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different levels. The material removed during the excavation of No. 2 has been built up into a large steep-fronted deltaic deposit lying just west of Priesthills. No. 3 channel, formed when the ice-front to the west stood at a level of about 1,150 feet, is only 20 to 30 ft. deep except at its lower end where it has cut a deep gorge through the delta fan of No. 2. Its waters and those of the conspicuous lower marginal cut marked No. 4 in Fig. 3 escaped south-eastwards by cutting a new overflow channel along what is now the lower part of the Ponesk Burn. The great gorge of this burn, over a mile long and up to 200 feet deep with almost vertical walls of felsite in places, served as a line of escape for the enormous volumes of water released during the later phases of retreat.

In this brief account only the main drainage channels have been mentioned. It should be added, however, that in the cases of Nos. 3 and 4 two or three subsidiary retreat stages can be made out. The drainage channels associated with these have intakes 10 or 20 feet below those of the main ones, but they do not extend far, the waters eventually finding their way back into the latter.

Lesmahagow District

Old Red Sandstone.—Mr. Ross completed the revision of the area of Lower Old Red Sandstone rocks on the north side of the Douglas coal basin and began a re-examination of the Carboniferous sediments. The former consist chiefly of massive red sandstones, mottled purple and red flags and subordinate marly bands. The best exposures are seen in the headwaters of the Linn Burn and in the River Nethan near Boughden Braes and Brownhill. The dip varies from E. to E.S.E. at angles of 12 to 35 degrees. A band of conglomerate, containing pebbles of greywacke and red chert, has been traced along the west slopes of Clarkston Strip and Hilltop Wood, the best section occurring in an old quarry east of Dillar's Corner. A number of intrusions of felsite and of quartz-porphyrite formerly quarried for road-metal have been mapped. The intrusions are inclined in the direction of the dip in the associated sediments, which they seem to cut at low angles.

Carboniferous.—From near Gateside south-westwards for some 3 miles the fault forming the boundary between the Old Red and the Carboniferous keeps close to the western bank of the Nethan. The examination of this faulted belt has been commenced, but the working out of the detailed local sequence from the broken and partial sections available has not been completed.

The ground is largely covered with drift of a sandy and gravelly nature. Where good sections are exposed this is seen to pass downwards into stiff, clayey material resembling the typical boulder-clay of other districts, and containing numerous fragments of greywacke, chert, and other Southern Upland

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types, many of which, however, may be derived at second-hand from the conglomerate bands in the Old Red Sandstone.

Several borings for coal have been visited and examined.

STIRLINGSHIRE

Mr. Read has revised the area lying along the Forth from the face of the Ochils at Bridge of Allan and Blairlogie southwards to Stirling.

Lower Old Red Sandstone.—In order to complete the revision of the six-inch sheets for publication Mr. Read has begun the mapping of the western part of the Ochils above Bridge of Allan, Airthrey Castle and Blairlogie. The great Ochil Fault which in this area forms the southern boundary of the volcanic and sedimentary rocks of Lower Old Red Sandstone age is, from Alva westwards, concealed beneath the carse clays or beneath gravels of the '100-ft.' beach. The general direction of the Ochil Fault can, however, be inferred as about E.N.E.–W.S.W. The fault passes through Menstrie, just S. of Blairlogie, N. of the Abbey Craig and so to Cornton. Further westwards along its line, chocolate coloured sandstones of Lower Old Red Sandstone age are seen in the banks of the Forth at Craigforth Mill, whilst, about half-a-mile to the south, lavas of Calciferous Sandstone age make Craigforth Hill, rising from the level Carse plain. The Ochil Fault runs between these two localities.

The Lower Old Red Sandstone rocks of this part of the Ochils consist of andesite lavas, extremely coarse agglomerates, conglomerates and sandstones, dipping a few degrees west of north at angles of 9° to 12°. They are cut up into blocks by large faults, which run in a general N.N.W.–S.S.E. direction. The downthrow is generally to the west, so that, for example, the lavas seen on the top of Dumyat (1,378 ft.) above Blairlogie, are, in a distance of less than a mile, thrown down to the level of the Carse edge (50 ft.), whilst, a little further west, they are faulted out of sight altogether. Above Blairlogie these N.N.W.–S.S.E. faults are often the sites of broad barytes veins, as described by Mr. G. V. Wilson.[1]

Upper Old Red Sandstone.—Near Spittal, at Causewayhead, alongside the Bridge of Allan road, there is an old quarry in false-bedded sandstone, usually mottled red and white, but in places greenish. Less conspicuous are thin bands of very coarse grit, sandy shale and a marl with white cornstone concretions. The rocks seen are exactly like those of Upper Old Red Sandstone age occurring below the Cementstones in the burns south of Gargunnock on the north side of the Campsie Hills. The quarry must lie south of the main Ochil Fault.

At Spittal, however, nothing is seen of the Cementstone Group or of the great volcanic series of the Campsie Hills, but

[1] 'Special Reports on the Mineral Resources of Great Britain, vol. ii., Barytes and Witherite' (*Mem. Geol. Surv.*), 1922, ed. 3, pp. 107, 108.

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in a nearly obscured quarry in the grounds of Abbeycraig Park, some 200 yards east of the Spittal quarry, there occurs a series of rocks, described in detail below, which are doubtless part of the Lower Limestone Group of the Carboniferous Limestone. The current view[1] appears to be that the Calciferous Sandstone lavas of the Campsie Hills have thinned out at Causewayhead; they are last seen on the Craigforth 'island' already mentioned. But what evidence there is appears to point to a faulted junction of the Upper Old Red Sandstone against the Lower Limestones at Causewayhead, for, in a garden, half way between the Spittal and Abbeycraig Park quarries, there is a small crag of whitish slickensided sandstone, much-broken fakes and squeezed fireclay, which all have the appearance of a fault-rock. The Spittal Upper Old Red Sandstone may therefore lie between the main Ochil Fault and another a little to the south, and the Campsie lavas may be thrown down out of sight.

Carboniferous.—Little is seen in the area of the Carboniferous sediments beneath the Stirling sill,[2] which forms the Abbey Craig on the north of the Forth, and the crags of Stirling Castle and the King's Park on the south.

At Abbey Craig the base of the sill is not visible; the neighbourhood of its top may be indicated by a finer-grained type of dolerite occurring in a quarry on the east side of the Craig, 300 yards north of Craigmill.

On the west, no rocks are exposed for some distance below the lowest visible part of the sill until the Abbeycraig Park quarry, already mentioned, is reached. Mr. C. H. Dinham measured the section some years ago and, since the quarry is now inaccessible, the following record is given :—

	Ft.	in.
At the top, limy looking blaes	1	3
Faky Limestone, some brachiopods, but fossils not well preserved or common	–	8
Solid blue Limestone, weathering bright yellow, with fossil fragments throughout, though chiefly showing on weathered surfaces. Small encrinites, fragments of Athyrids, Productids, &c.	1	2
Faky Limestone, yellowish weathering, grey with reddish brown streaks	–	4
Gap, probably fakes or blaes, about	–	6
Rotten sandy faky fireclay with red patches	–	4
Coarse quartzose sandstone, with some quartz pebbles more than ¼ in. long, in thick posts with occasional partings only, at least 30-36 ft.		

These rocks undoubtedly belong to the Lower Limestone Group, and the sill at Abbey Craig most probably is intruded into the Limestone Coal Group.

[1] H. W. Monckton, *Proc. Geol. Assoc.*, vol. xii., 1892, p. 243; Sir Archibald Geikie, *Trans. Roy. Soc. Edin.*, vol. xxix., 1879, p. 450; also 'Ancient Volcanoes of Great Britain,' vol. i., 1897, p. 384.

[2] H. W. Monckton, *loc. cit.*, p. 202; *Quart. Journ. Geol. Soc.*, vol. li., 1895, pp. 480–492.

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Beneath the Stirling Castle portion of the sill, the junction of the dolerite with the underlying sediments was formerly visible at a point N. of Ballingeich Cemetery, where, beneath the chilled margin of the intrusion, there occurred 'calmstone' or hardened shales.

At Ballengeich Pass, about 240 yards E. of Raploch School, the following section may be seen :—

	Ft.	in.
Faky sandstone and sandstone, top not seen	3	6
Dark blue parroty micaceous fakes, with many fish scales and teeth, and some poor *Lingula*	–	6
Bright Coal	–	4
Coaly sandy fireclay	–	1–2
Coal	–	1
Coaly fireclay	–	2
Faky sandstone, with irony balls	4	2
Black blaes and few ironstone balls	2	7
Faky sandstone, varying from 1½ ft. to	3	6
Sandstone	3	6
Dark grey, thin-splitting fakes	1	11
Ironstone band	–	1
Grey fakes	–	4
Fakes and faky blaes	5	6
Nodular limestone band	–	2–3
Fireclay	–	5
Coal, bright	–	1
Fireclay	1	–

The section of the upper coal, with the fossiliferous parrot above it, is extremely like that of the Milton Coal of Bannockburn as observed by Mr. C. H. Dinham in the Bannock Burn, at Milton, The Milton Coal lies some 20 fms. below the Black Metals in the Limestone Coal group.

From bores around Raploch, it appears that there is a considerable thickness of strata, probably including the whole of the Lower Limestone Group, below the Stirling sill in that neighbourhood.

No sediments are seen beneath that part of the Stirling sill which forms the crags of the King's Park.

From the evidence given above, it appears probable that at both Abbey Craig and Stirling Castle, the sill is intruded in the Limestone Coal group a short distance below the Black Metals. Mr. Dinham[1] has shown that in the Bannock Burn, 4 to 5 miles S.S.W. of Stirling, the base of the sill lies about 14 fms. above the Murrayshall (Hurlet) Limestone. The difference in stratigraphical level of the intrusion at these two points is, roughly, 100 fms.

Raised Beaches.—From Bridge of Allan to Blairlogie Church the coast line of the '100-ft.' beach is well marked at a level of about 140 ft. Southwards from this coast line at Airthrey to the Abbey Craig 'island' there stretches a much-dissected flat-topped terrace of brownish sandy gravels. Two small islets of boulder-clay stood out of the '100-ft.' sea to the north of Causewayhead.

[1] 'Summary of Progress' for 1919 (*Mem. Geol. Surv.*), 1920, pp. 35–40.

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During Carse times the Abbey Craig was connected with the Airthrey 'mainland' by these '100-ft.' deposits. The flat clay grounds of the Carse have their margin at 50 ft. and extend into many old bays such as those at Touch House, Cambusbarron, King's Park Farm and east of the Abbey Craig.

Clackmannanshire

Mr. Haldane continued the revision of the ground lying to the east of Alloa. Many fresh exposures of coals, opened along outcrops during the strike of April to June, were noted.

The following is a composite general section of the strata below the Coalsnaughton Main Coal (4 ft. thick) and should be read as a continuation of the vertical section of the Clackmannanshire coalfield, published by the Geological Survey in 1877 :—

	Thickness Fms.	ft.	in.	Depth. Fms.	ft.	in.
Coalsnaughton Main Coal	–	–	–		—	
Blaes	–	–	9		—	
Sandstone	2	5	–		—	
Fakes and blaes with a 9-in. sandstone rib	1	5	10		—	
Coal	–	–	8	5	–	3
Faky blaes	–	2	8		—	
Sandstone	1	4	3		—	
Fakes and blaes	–	5	3		—	
Coal ('Mid Cherry' or 'Mill')	–	2	1	8	2	6
Faky blaes	1	2	5		—	
Sandstone	1	4	8		—	
Faky blaes	–	5	11		—	
Fireclay	–	–	4		—	
Coal	–	–	7	12	4	5
Coaly blaes	–	–	2		—	
Faky fireclay	–	4	6		—	
Sandstone	1	–	6		—	
Fakes	–	–	6		—	
Coal	–	–	6	14	4	7
Coaly blaes	–	–	3		—	
Fireclay	–	5	8		—	
Sandstone	6	3	8		—	
Fireclay	–	–	8		—	
Coal	–	–	9		—	
Faky rib ('Lower Splint' or 'Ball')	–	–	5		—	
Coal	–	2	3	23	–	3
Fireclay and fakes	–	1	8		—	
Sandstone	–	2	9		—	
Fakes	–	–	2		—	
Ironstone ball	–	–	3	23	5	1
Shaly blaes	–	1	6		—	
Sandstone	4	3	5		—	
Fireclay	–	–	7		—	
Coal	–	–	9		—	
Fireclay	–	2	6		—	
Coal	–	1	–	29	2	10
Blaes	–	–	2	29	3	–
Coal	–	1	6	29	4	6
Sandstone	3	1	4		—	
Coaly blaes	–	2	–		—	
Fireclay and balls	–	3	–		—	
Blaes and balls	–	1	7	34	–	5

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This last item is taken as the probable base of the Coal Measures and is followed in downward succession by a series of sandstones more than 18 fms. thick. On this view the total thickness of Productive Coal Measures present in this field is about 136 fms., although it no doubt varies somewhat for different parts.

The coal seams and their associated strata show considerable variation. Thus the Coalsnaughton Main is usually split into two or more leaves by hard 'stone' partings, though occasionally found as one seam with an average thickness of 3½ ft. The roof may be of sandstone or blaes, the pavement of sandstone, blaes or fireclay. The 'Mid-Cherry' Coal generally occurs as a single seam, while the 'Lower Splint' usually shows one or more partings. These names are purely local and not very satisfactory. There is diversity of opinion regarding the correct nomenclature and the same coal may pass under different names in adjoining fields. Correlation is rendered difficult by the absence of fossiliferous index-horizons, and by the fact that few bores have been put down of recent years, while many of the old boring records afford little help. The following group correlation with the Lanarkshire sequence is merely a tentative one :—

Lanarkshire.	Clackmannanshire.
(1) Upper Coals (down to Virtuewell).	(1) Down to Nine-foot Coal.
(2) Kiltongue-Drumgray Coals (K. Musselband to Lower Drumgray).	(2) Crowburn Ironstone to Coalsnaughton Main Coal.
(3) Armadale Coals (Mill to Crofthead).	(3) From "Mid Cherry" downwards.

Central Coalfield

In addition to the routine revision work carried on in other coalfields, every opportunity was taken to keep in touch with borings in progress in the Central coalfield. The total length of cores of which annotated records have been made and filed during the past year in this coalfield alone amounts to over 8,000 feet. Much economic and scientific information has thus been collected which would otherwise have been largely lost, and for permission to examine the borings our thanks are due to the various colliery companies concerned.

In most cases the records are confidential in the meantime, but through the courtesy of Mr. H. M. Cadell, of Grange, we are able to summarise the results of several borings made by him in the Bo'ness district. The first of these was put down at the old quarries at Burnfoot (Linlithgow, 1 N.E.), and started a short distance below the crop of No. 1 Carriden Limestone.

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The total depth was 76 fms. and the following are the more important items recorded :—

	Thickness. Fms.	ft.	in.	Depth from surface. Fms.	ft.	in.
Fakes and sandstone	6	5	4	6	5	4
Faky blaes	–	3	8	7	3	–
Blaes and balls; scattered shells	1	5	–	9	2	–
Limy fakes	–	–	3	9	2	3
Hard crinoidal LIMESTONE (No. 2 CARRIDEN)	–	2	10	9	5	1
Blaes and fireclay	–	4	8	10	3	9
Limestone rib	–	–	7	10	4	4
Ashy fakes	1	–	8	11	5	–
Ash, bedded; with occasional plant fragments (CARRIDEN ASH)	5	4	5	17	3	5
Blaes	–	–	3	17	3	8
COAL with a 1-in. rib	–	2	6	18	–	2
Blaes	1	4	5	19	4	7
Hard crinoidal LIMESTONE (No. 3 CARRIDEN)	–	1	4	19	5	11
Strata; chiefly fakes	3	0	1	23	–	–
Limy fakes	–	3	–	23	3	–
Shelly LIMESTONE (No. 4. CARRIDEN)	–	–	5	23	3	5
Shelly blaes	–	5	–	24	2	5
Fakes	–	–	4	24	2	9
COAL	–	–	8	24	3	5
Strata; mainly fakes; some thin ash beds and limy ribs	12	–	1	36	3	6
Blaes	1	–	10	37	4	4
Limy blaes	–	1	11	38	–	3
Sandy LIMESTONE		2	–	38	2	3
COAL	–	–	1	38	2	4
Fakes; some shell fragments at top	–	1	7	38	3	11
COAL	–	–	7	38	4	6
Strata; sandstone above, fakes below	8	5	11	47	4	5
Faky blaes; a few shells at 48½ fms.	5	–	4	52	4	9
Blaes with scattered shells and shelly ribs	5	5	5	58	4	2
LIMESTONE; crinoidal top; LITHOSTROTION band (No. 5)	1	5	2	60	3	4
Shelly blaes	1	–	3	61	3	7
Fakes and faky sandstone with some blaes	3	5	4	65	2	11
Pale coloured nodular rooty LIMESTONE; no fossils	–	1	6	65	4	5
Strata chiefly fakes and blaes	10	1	8	76	–	1
Total	76	–	1	—		

Another bore at Kinningars Park, almost ½ mile west of the preceding, proved the sequence from the Easter Main Coal down to No. 3 Carriden Limestone. Three marine horizons occur between the Easter Main and Smithy Coals, the lowest in the blaes above the latter seam. Immediately on top of the Smithy Coal occurs a dolerite sill, 16 fms. thick, recently described in detail by Mr. Cadell.[1] Its extremely vesicular top and bottom suggest intrusion under comparatively little cover. Thirteen

[1] *Trans. Inst. Min. Eng.*, vol. lix., 1920, p. 271.

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and a half fathoms below the Smithy Coal is the first of the Carriden Limestones, 22 inches thick; while No. 2 Carriden Limestone was met with 12⅔ fms. lower. From the blaes below the latter *Posidonomya corrugata* was obtained. The Carriden Ash is here represented by a few feet of ashy marl. From the blaes overlying No. 5 Limestone at Burnfoot has been obtained a fauna which suggests comparison with the Neilson Shell-bed overlying the Blackhall Limestone. On the same horizon lie the Fankerton Limestone of the R. Carron above Denny and the 'A' and 'B' Limestones of the Bannock Burn described by Mr. C. H. Dinham in the 'Summary of Progress for 1920' (pp. 35–38). Carriden No. 5 Limestone again is probably represented on the north side of the Forth by the thick Charlestown bed. Here two marine limestones, of which the lowest appears on stratigraphical and faunal grounds to be the equivalent of the Hurlet, are known to underlie the thick limestone. The Burnfoot bore did not go deep enough, it would seem, to prove these; but another boring, 400 feet east of Carras Gate, found a 2-foot crinoidal limestone overlying an 8-inch coal 9½ fms. below No. 5. There were clear signs of faulting between the two, and the lower bed perhaps represents the marine limestone occurring both at Charleston and in the Bannock Burn ('C' Limestone or Sandy Encrinital Limestone of Campsie) approximately midway between the Blackhall and Hurlet.

3. Borings for Oil at D'Arcy and West Calder

D'Arcy Oil Well.—In the Summary of Progress for 1920 an account of this boring was given to a depth of 150 fms. During 1921 the depth has been increased to 212 fms. From 150 to 175 fms. the beds consist of sandstones and shales with two thin seams of coal, probably only a few inches in thickness. At about 177 fms. there occurs a shale approaching to an oil-shale and which may represent one of the shales worked at Straiton, 6 miles to the west. Green and red mottled marls were drilled through between 181 fms. and 188 fms. below which the boring to a depth of 212 fms. continued in dark marly shales in which are three thin bands of limestone. Both the limestone and the shale contain entomostraca.

The boring was visited periodically and the samples examined by Mr. Tait, who from the type of sediments, especially the dark shales containing fish scales and entomostraca, considers that the boring is still proceeding in the Oil Shale Series.

West Calder Oil-Well.—Boring ceased on the 24th October 1921, at a depth of 3,923 ft., which is 17 ft. deeper than that given in the account in the Summary for 1920. The well proved unproductive and the hole is being filled.

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4. West Highland District

E. B. Bailey, M.C., B.A., District Geologist.
J. E. Richey, M.C., B.A. } Geologists.
V. A. Eyles, B.Sc. }
John B. Simpson, B.Sc. }

Moine Gneiss of Ardnamurchan

The work of the past season has shown that the metamorphic rocks of the western half of the Ardnamurchan peninsula are divisible into three major belts of which the western and eastern are psammitic in constitution, and the intervening one pelitic. The course of the pelitic belt runs roughly north and south from Carn Mòr, at the mouth of Loch Moidart, to Carna, in Loch Sunart. Its outcrop in general measures about a mile across, but, along the shores of Loch Sunart, folding leads to its having a breadth of 2½ miles. In the sequel, this gneiss will be spoken of as the Carna Pelitic.

Three main points of interest have been noted in regard to the psammitic rocks west of the Carna Pelitic :—

(1) Relict grains, or small pebbles of quartz and felspar, are recognisable throughout the whole belt. They become a conspicuous feature in certain particularly massive false-bedded gneisses, the outcrop of which extends, on the north coast, for two miles west from the Carna Pelitic, but southwards fails altogether in the upper reaches of Glenborrodale. Most of the rocks of the western psammitic belt may be described as flaggy rather than massive.

(2) Mr. Richey found a very low grade of metamorphism in the more westerly exposures of the belt at intervals along the coast between Ben Hiant and Kilchoan. The pre-Mesozoic foundation here consists, not of gneiss, but of well-bedded white felspathic grits, often pebbly and usually much sheared. East of Ben Hiant, more highly metamorphosed rocks are encountered characterised by pink felspar and obvious biotite. The Tertiary igneous rocks of Ben Hiant separate these two types as exposed along the shore section. The ground north of Ben Hiant, where their relations may perhaps be made out, has not yet been mapped.

(3) It has been found possible to map an approximate boundary for the massive gneiss mentioned under (1), even where it is in contact with the more widespread flaggy variety. Great assistance is afforded by the fact that the massive gneiss gives rise to some of the barest rock-scenery of the Highlands, whereas its flaggy associate disintegrates freely, and is for the most part covered by grass. On the north coast, Mr. Bailey finds the massive gneiss in contact on its eastern side with the Carna Pelitic. South of Lochan nam Fiann, Mr. Simpson finds flaggy gneiss inserting itself between the two; and in Glen Borrodale he has traced it sweeping round the termination of the massive gneiss to join with the main flaggy outcrop to north and west. It seems probable that the omission of the flaggy gneiss along the contact of the massive psammitic and pelitic belts, where these come together for three miles between the coast and Lochan nam Fiann, is due to a dislocation. At any rate there is a general discordance of strike of about 40° on the two sides of the boundary, and, though this becomes less marked at the actual contact (only exposed at two places according to Mr. Bailey), it remains

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clearly appreciable. The two contact exposures are of limited extent, but they show very little crushing, so that they suggest movement dating from the period of folding, rather than subsequent faulting. Some may prefer to claim the discordance as evidence of a stratigraphical unconformity, showing that the Carna Pelitic is of later date than its western neighbours.

The Carna Pelitic in much of its course, as, for instance, where it has been mapped by Mr. Simpson on the north shore of Loch Sunart opposite Carna, consists of three main divisions—an eastern and a western band of garnet-gneiss, and an intervening mixed assemblage of pelitic, semi-pelitic, and psammitic character, in which sandy calcareous seams are not infrequent. Near Loch Sunart the middle mixed division has a mean breadth of half a mile and it continues thus for 3½ miles northwards, and then thins away to nothing. For the next 3 miles it is unrecognisable, but north of Kentra Bay it puts in an appearance, and where it reaches the south channel of Loch Moidart, Mr. Eyles finds that its outcrop is almost half-a-mile broad.

The psammitic gneiss which lies east of the Carna Pelitic differs somewhat markedly from the western psammitic, in that it shows no recognisable pebbles of quartz and felspar. It is often very massive and bare of vegetation.

The difference of character of the two psammitic belts flanking the Carna Pelitic makes it rather difficult to account for the inconstancy of the middle division of the later as a result of folding.

TERTIARY IGNEOUS COMPLEX OF ARDNAMURCHAN

During the past season Mr. Richey has made progress in the investigation of two well-known centres of interest, the Ben Hiant vent and the Ardnamurchan gabbro.

In the following serial remarks, attention is restricted to that part of the Ben Hiant vent which lies in a general way east of the great intrusion forming the summit of the hill.

(1) The agglomerates so well exposed on the south and east sides of Ben Hiant include bands of fine-grained tuff. Where not horizontal, these bands are inclined into the hill, usually at low angles. Along the cliffs N.E. of Maclean's Nose individual bands are seen to continue for at least 100 yards.

(2) The junction between the agglomerate and the walls of the vent is on view in many sections. In the south portion of the hill the junction is vertical. On the east face and on an adjoining northern face it is inclined at angles of from 30° to 50° into the hill, *i.e.*, to west and south respectively; and tuff bands that here occur in the agglomerate are similarly inclined.

(3) A few sheets of inninmorite-pitchstone, up to 30 ft. in thickness, are associated with the agglomerates on the south side of the hill, into which they dip at low angles conformably to the bedding shown by the tuff bands in the agglomerates. Individual sheets consist of two portions :—

(*a*) A lower solid portion, with prismatic jointing forming upright hexagonal columns.

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(*b*) An upper amygdaloidal portion, with flat hexagonal columns of smaller diameter than the upright set of the lower portion.

A stream E. of Stallachan Dubha shows a sheet with the one set of columns curving round into the direction of the other. The base of this sheet rests on a fine-grained tuff which is baked for a depth of 2 ft. from the junction. The actual top of the sheet is not exposed.

Thin intrusive squirts of subvitreous pitchstone, evidently derived from the same magma, are a feature of the interior of these sheets. It is suggested that the pitchstone sheets are lava flows within the crater.

(4) A third of a mile S.E. of Ben Hiant summit, there is a line along which two prominent pitchstone sheets terminate abruptly. The margin of the vent takes a bend along the course of this line a little further downhill. Perhaps the line marks the course of a fault or the boundary of a secondary blow-hole that gave rise to a vertical wall against which later extruded pitchstone sheets abut.

(5) An area of porphyritic dolerite about ½ mile wide, occurs in the south portion of the vent between the outcrop of the two pitchstone sheets mentioned and Stallachan Dubha. The rock is characterised in the field by its spheroidal weathering. A steeply inclined clean-cut junction between it and agglomerate is exposed for 20 ft. in one of the stream gullies, just E. of the pitchstone sheets. The groundmass of the dolerite becomes somewhat vitreous within a few yards of the junction, but is not further chilled. The agglomerate appears to be unbaked.

(6) Abundant large blocks of basalt with conspicuous felspar phenocrysts characterise the agglomerates of the south portion of the vent. Some of the blocks are of enormous size. Nothing like them is met with farther north-east.

The great gabbro mass of Ardnamurchan Point is an intrusive complex which includes various types of gabbro as well as more acid rocks. The outer boundary of the complex has been traced from the northern side of the peninsula near Plocaig in an elliptical curve reaching the Sound of Mull, 3 miles S.S.E of the Point of Ardnamurchan. In addition, an isolated coastal exposure of a junction between gabbro and sediment has been found at the north end of Garbhlach Mhor. The complex area, about 7 miles long by 4 miles across, is disposed with the long axis bearing N. 60° E.

A small mass of acid rock, first recorded by Professor Busz,[1] lies between Achnaha and Glen Drian, and appears to mark a focus around which various more basic intrusions are disposed in a manner recalling the arrangement of the ring-dykes of Mull. The mass is situated a little to the N.E. of the centre; it has an elliptical outcrop with a major axis orientated in the same direction as that of the complex. The rock is allied to the tonalites and quartz-monzonites, and it becomes fine-grained towards its edge, where it sends numerous apophyses into the surrounding rocks, as may be seen in roadside exposures ¼ mile S.E. of Achnaha. The boundary lines of the various intrusions, surrounding the quartz-

[1] K. Busz in *Rep. Brit. Assoc.* for 1900, Bradford, p. 751.

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monzonite, so far as they have been investigated, follow a direction roughly parallel to the outer boundary of the whole complex. While the complex is free from the minor intrusions that so obscure the ring-dykes of Mull, its mapping is rendered difficult owing to the absence of screens of 'country-rock' which in Mull so often separate adjoining intrusions.

Progress has been made in the mapping of the country immediately outside the plutonic complex where minor intrusions (cone-sheets and sills) occur in enormous profusion. In numerous observed junctions of cone-sheets and sills, the former invariably cut and are chilled against the latter.

LEWISIAN COMPLEX OF COLL

One of the most debated points in Scottish geology for many years past has been the relations of the igneous and sedimentary portions of the Lewisian complex. Last season it was found that sediment enters largely into the eastern half of Coll. There are good coast sections, and it is possible to prove that the sedimentary gneisses here antedate the igneous, a relationship which Clough[1] considered probable both in the Loch Maree and the Glenelg districts of the North-west Highlands.

The north-east portion of Coll was mapped by Mr. Eyles, the central part by Mr. Bailey, and the south-west end by Mr. Simpson.

Igneous Gneisses.—The orthogneisses of Coll are for the most part intermediate or acid in composition, and granitic in texture. The prevalent type is a well-banded grey hornblende-biotite-gneiss, quartz-diorite in all but structure. Next to it in bulk is a comparatively unbanded pink acid rock, typical granite-gneiss.

A characteristic feature of the grey gneiss is the common occurrence within it of certain hornblendic layers, which, as several observers[2] in other regions have suggested, may be laminar inclusions of previously consolidated basic igneous rock. There are also some important outcrops of hornblende-schist associated with the sedimentary gneisses, and these are interpreted as intrusions.

Sedimentary.—The paragneisses of Coll consist mainly of magnesian marbles, quartz-granulites, and felspar-biotite-granulites. The mineral associations of the marbles and quartz-granulites are such as to leave no doubt that these rocks are metamorphic sediments. The felspar-biotite-granulites are more difficult to interpret. They are rather fine-textured rocks, consisting in large measure of granules of plagioclase associated

[1] C. T. Clough in 'The Geology of Glenelg' (*Mem. Geol. Surv.*), 1910. p. 19.

[2] *Cf.* C. E. Tilley, 'The Granitoid Gneisses of Southern Eyre Peninsula (South Australia) and their Associated Amphibolites,' *Quart. Journ. Geol. Soc.*, vol. lxxvii., 1921, pp. 81, 127.

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with evenly distributed, well orientated flakes of biotite; pink garnet in small crystals is a common accessory. The felspar-biotite-granulites are an easily recognisable type, largely on account of their fine texture, so that their distribution in Coll is thoroughly known. With trifling and easily understood exceptions, wherever felspar-biotite-granulite occurs, the more obvious sedimentary types (marble, quartz-granulite, or some type intermediate between these and felspar-biotite-granulite) are sure to be found also. This close association, coupled with the occurrence of intermediate types, and the frequent development of garnet (a very rare mineral otherwise in Coll) leads to the conclusion that the felspar-biotite-granulites are of sedimentary origin.

Quartz-granulites are best exposed at Ben Feall (east of Feall Bay), and impure marbles are also found on the eastern side of this headland. Rudha nan Uan (west of Hogh Bay) consists mainly of felspar-biotite-granulites. Another easily accessible exposure of marble is on the east shore of Loch Gorton

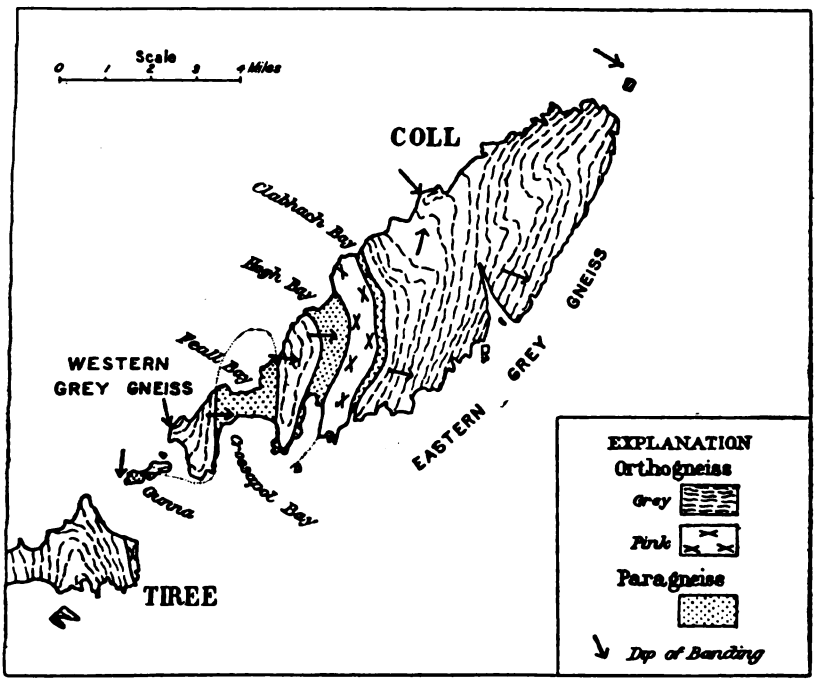

FIG. 4.—*Geological Map of the Island of Coll.*

at the south end of the Clabhach belt of sediment (*see* Fig. 4). A conspicuous feature of this Clabhach sedimentary belt is an outcrop of porcellanous quartz-rock, ranging from 15 ft. thick at Clabhach Bay to about 200 ft. thick where it crosses the road at Acha (3 miles farther south). Probably this quartz-rock is a metamorphosed sandstone, but possibly it is a quartz-vein.

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All the sedimentary types except the felspar-biotite-granulites are well-banded, and it is reasonable to interpret their banding as bedding. The cliffs of Ben Feall exhibit in imposing fashion the banding of the quartz-granulites, and it is certainly a more regular structure than the flow-banding of the orthogneisses.

DISTRIBUTION

The text-figure gives a good idea of the distribution of the ortho- and paragneisses of Coll. The grey banded type of orthogneiss has an important development north and east of the paragneisses or sediments. It can, in this outcrop, be properly described as overlying the sediments so far as observation reveals a relationship. West of this and actually within the sediments comes a great sheet of pink granite-gneiss some 2,500 feet thick, which runs south from Ben Hogh (east of Hogh Bay). Westwards, beyond the Hogh Bay outcrop of sediments, one meets once more with grey banded gneiss, which, however, almost certainly belongs to a mass or complex quite distinct from that of the eastern tract previously mentioned. The grey gneiss west of Hogh Bay is found on further enquiry to be contained in a fold which closes towards the south just as the south shore of the island is reached. Another similar southward closing fold of grey banded orthogneiss is met with west of Feall Bay.

The outcrops of dark hornblende-schist within or bordering the sedimentary belt, though of considerable breadth, are not large enough to be represented in the text-figure. A very good exposure occurs at the west end of Hogh Bay. There is also a minor outcrop of grey orthogneiss within the sediments, less than $\frac{1}{4}$ mile west of the Ben Hogh granite-gneiss. It has been traced for 2 miles, and is easily located on the ground where it gives rise to a gentle ridge known as Broadhills.

The sedimentary rocks have, with local exceptions, determined low-lying tracts in which superficial deposits such as blown sand and alluvium conceal much of the geology. Thus, while there are plenty of exposures to enable the accurate mapping of boundaries between ortho- and paragneisses, and while the coast sections afford good opportunities of studying marginal and other relationships, it has not been found possible to map out the various sedimentary types.

As a rough approximation it may be suggested that the sediments of the Clabhach belt are about 300 ft. thick and those of Hogh Bay about 2,500 ft.

Particular attention was given to the question of the relations of the sedimentary and igneous portions of the Coll complex. At various points decisive evidence was obtained that the igneous rocks are later than, and intrusive into, the sediments.

The most convincing exposure is half way up the west shore of Crossapol Bay ($\frac{3}{4}$ mile S. of Crossapol House), The sedimentary rocks here are felspar-biotite-granulites, often garnetiferous.

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Their main junction with the grey orthogneiss of the district runs out to sea just west of Port an Duine (a locality named on the 6-inch map, Argyll 50 S.W.). Just north-east of this the coastline takes a rather pronounced bend, and here, about 150 yds. within the boundary of the sediments, there occurs a band, some 20 yds. wide, of typical grey gneiss with layers and lenticles of hornblende-schist. It has been traced along the sea margin northwards for 400 yds. to its termination. This band envelops many thin layers and lenticles of the felspar-biotite-granulites. These are commonly three or four inches thick, but occasionally less. There does not seem any room for doubt that the grey orthogneiss has here invaded the granulite.

Another exposure occurs at the northern margin of the sandy shore of Hogh Bay. Sediment, represented by quartzose biotite-granulite, is here seen within a few feet of normal Ben Hogh granite-gneiss. Between, there is a grey igneous gneiss of variable nature which seems to interdigitate with, and at places merge into, its two neighbours. It is sometimes strikingly xenolithic with lumps rich in green hornblende. A few of the xenoliths are pale, and one such on slicing was found to consist of malacolite, basic felspar, calcite, and green hornblende. There can be little doubt that these xenoliths represent impure marbles derived from some portion of the sedimentary belt. Every stage of absorption can be traced with the ultimate production of hornblendic gneiss of peculiar type.

Following the top of the cliffs northwards for some 500 yds., one enters a belt of the Hogh granite-gneiss where xenoliths of felspar-biotite-granulite are widely distributed. Here again it seems fairly certain that the Hogh granite-gneiss is including fragments of one of the characteristic types of Coll sediments.

The Hogh Bay phenomena of xenoliths and contamination are re-exposed where the western margin of the Hogh Bay granite-gneiss skirts the eastern shore of Loch Breachacha. A slide from the narrow contaminated zone shows a typical norite-gneiss, and so recalls observations made by Lacroix[1] in contact-zones of the Pyrenees.

These details show that the igneous rocks of the Coll complex are intrusive into the sediments. Probably this accounts for the striking concordance of the two sets of rocks at every contact. Certainly it affords a very simple solution for the unique character of the Ben Hogh granite-gneiss—a feature which would be hard to explain on any hypothesis which interpreted the Ben Hogh belt as an infold of a general floor of pre-sedimentary orthogneiss.

Flinty Crushes.—A point of considerable interest is the frequency of flinty crush-rock in some parts of Coll. Examples have been found more particularly along the northern half of the east coast.

[1] A. Lacroix, 'Le Granite des Pyrénées et ses Phénomènes de Contact,' *Bull. des Services de la Carte géologique de la France*, Tome x., 1898–99, p. 263.

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CAMPTONITE DYKES

Messrs. Bailey, Eyles and Simpson record camptonites among the late dyke-rocks of Coll and Tiree, and also from Ardnamurchan east of Hacarsaid. In ten out of eleven coastal exposures of camptonite dykes in Coll, the direction is N.W. or W.N.W. In 15 out of 25 coastal exposures in Ardnamurchan the direction lies roughly between N.N.W. and W.N.W. In three cases camptonites are seen cut by basalt dykes of normal Tertiary appearance, a relation in conformity with a rule which Dr. Clough and others have found to hold in the West Highlands generally. Owing to the absence of camptonite dykes in the gneiss areas of Western Ardnamurchan, no opportunity is afforded there of testing the age of these dykes against the Mesozoic sediments or Tertiary lavas.

PRE-GLACIAL MARINE EROSION

Mr. Richey reports a hitherto undescribed occurrence of a shore-line in Ardnamurchan apparently corresponding with Mr. Wright's[1] pre-Glacial coast of western Mull, the Treshnish Isles and Colonsay.

It is marked by a level rock-notch on the hill slopes above Kilchoan Bay, where for a mile it is a conspicuous feature of the landscape. At its north-east end it was found to stand 145 ft. above O.D. This is some 20 ft. higher than on the west coast of Mull, but the pre-Glacial sea-cave of Ulva, described by Mr. Burnett in last year's Summary of Progress (p. 42), has a floor at 150 ft. above high-water mark (roughly speaking, 155 ft. above O.D.).

The pre-Glacial age of this high-level Kilchoan notch seems to follow with probability from the following facts :—

(1) No gravels are preserved in connection with the notch. The highest gravels are those of the late-Glacial 100-foot beach exposed, for instance, at the Free Church Manse.

(2) The platform of the notch has suffered a modelling by erosion, which does not seem to have affected the late-Glacial and post-Glacial beach-gravels, occurring as well preserved flats at lower levels.

Ice Flow.—Numerous striæ show that the Ardnamurchan peninsula has been crossed obliquely by ice, moving in a general west-north-west direction. In Coll, evidence is much more difficult to obtain, but Messrs. Bailey and Eyles noted a few striæ at various points in the north-east half of the island which are also directed approximately W.N.W. Their observations here agree with those of Professor James Geikie.

As might be expected, blocks of the great Morven granite are to be met with at intervals in all parts of Ardnamurchan. In Coll, erratics are curiously few, so that it is worth drawing attention to a conspicuous black boulder, 8 × 7 × 4 ft. mounted 200 ft. above sea-level on the pale rocky slopes of Ben

[1] W. B. Wright, 'Pre-glacial Shoreline in the Western Isles of Scotland,' *Geol. Mag.*, 1911, p. 97.

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Hogh, 300 yds. north-west of the head of Loch nan Cinneachan. The boulder consists of olivine-gabbro of Tertiary type.

ECONOMICS

The Raasay Ironstone is exposed in the shore section westwards of Kilchoan at the following localities situated one mile apart :—

(1) Below high water mark, ⅛ mile S.W. of landing jetty, Port Mor, Kilchoan, and 700 yds. E. 10 N. of trigonometrical station on Maol Buidhe.

(2) Below high-water mark, 970 yds.W. 8° N. of trigonometrical station on Maol Buidhe. Owing to the sea-cliffs this place is somewhat difficult of access. It may be reached when the tide is out, along the shore from the east, or by a steep path down the cliff, which gains the shore a little east of the exposure.

At locality (1) the Upper Lias shales are riddled by basic sheets and sills, and so occur in disconnected areas of small extent. In one of these, Dr. G. W. Lee was led to an outcrop of the Raasay Ironstone by the occurrence in the underlying shales of the *Harpoceras-Dactylioceras* fauna typical of the horizon in Raasay. The ironstone appears unaltered by the igneous intrusions. It is limy and oolitic with shaly layers, and contains belemnites. Its top is not exposed, and the total thickness seen is about 2 feet.

At locality (2) the strata are fairly free of minor intrusions, but are highly baked by the neighbouring gabbro mass. The Upper Lias shales were recognised here by Mr. Richey from their position between strata taken to represent the Middle Lias and Inferior Oolite respectively. The ironstone is altered to magnetite, but belemnites can be recognised in it. The seam is fairly solid with shaly layers. It is fully exposed and is 4 ft. thick.

On Ardnamurchan, owing to the profusion of igneous intrusions, there is absolutely no prospect of the Raasay Ironstone proving of economic value (*see* p. 109). It may occur below the Tertiary lavas in the extreme north of Mull. If a search by boring were ever contemplated there, the locality suggested is the promontory between the Ardmore and Bloody bays, which is about 3 miles south of the Ardnamurchan outcrops. There, on the west side of Bloody Bay, about 1¼ miles S.E. of Ardmore farm, a massive red sandstone[1] immediately underlies the lavas. Its age is unknown, but it is at any rate later than the Lias.

It may be mentioned that a reddish sandstone of Inferior Oolite age occurs on the opposite Ardnamurchan shore, east of Sron Bheag point, and this may perhaps be the position of the sandstone of Bloody Bay.

Mr. Ennos has completed the estimation of iron in the magnetic ore referred to in the " Summary of Progress " for 1920 (p. 43),

[1] ' Summary of Progress ' for 1920 (*Mem. Geol. Surv.*), 1921, p. 37.

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as occurring in two localities near the southern end of Iona. He finds in each case between 29 and 30 per cent. of metallic iron, corresponding to about 40 per cent. of magnetite. The degree of concentration is thus not great enough to make the deposits likely to be of value.

5. North Highland District

M. Macgregor, M.A., B.Sc., District Geologist.
G. V. Wilson, B.Sc.
H. H. Read, M.Sc., A.R.C.Sc.
D. Haldane, B.Sc.
G. Ross, B.Sc. } Geologists.

Field-work was carried on during the summer months in the northern and central parts of one-inch Sheet 102 west of Loch Shin and along the Oykell and Lower Cassley valleys. The survey was extended westwards as far as Oykell Bridge, and the only part of the Sheet not yet examined is an area of about 30 square miles along the south-western margin between Lubcroy and Corriemulzie. The ground reported on below lies partly in Ross-shire, partly in Sutherland.

Ross-shire

On the south side of the river Oykell (the county boundary) the area mapped by Messrs. Read, Haldane and Ross stretches from the lower part of the Einig eastwards to Wester Rhelonie, and extends southwards to the Oykell–Carron watershed. Mr. Ross finds that the rocks in the western part of this strip are almost entirely siliceous schists varying in type from massive and rather coarse-grained quartzo-felspathic gneisses to more flaggy schists rich in muscovite. The former type is well-exposed in the gorge of the Oykell to the west of Torr a' Chorcain and along the belt of shattered rock which crosses Beinn Chreagach. Good sections of the more flaggy type occur in the Allt Mòr and its tributaries, where the dip is uniformly S.W. at angles of 25 to 50 degrees; and in the Einig, where the flags are somewhat thicker (6 to 10 in.) and the dip varies from S.S.E. to S. at angles of 25 to 40 degrees. Bands of a semi-pelitic facies are rare but occur at one or two localities, *e.g.*, to the east of Lochan Phail on the north bank of the Allt Mòr.

The shattered rocks on the north-west edge of the Beinn Chreagach ridge give rise to a conspicuous line of scree slopes extending south-westwards from Creag Langwell. A similar but much more marked shatter-belt extends from Creag Langwell westwards across the upper streams of the Alltan Beaga and along the steep southern bank of the Oykell south of Loch Thurnaig, and then, turning south-east, crosses the Einig about 500 yds. N. of the mouth of the Allt nan Caisean. The same crush-line is well-exposed east of Langwell in the burn at

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Brae, where Mr. Read finds the granulites to be contorted and brecciated with much iron staining in the crush-jaws. East of this locality, however, it cannot be followed, for at Doune and at Innis nan Damh the undisturbed and regularly dipping flags occur right across its line. The country rock here consists of the usual pale-coloured siliceous granulites showing here and there pebbles of pink felspar (*cf.* p. 100). The dip is usually high and varies in direction from S. towards S.S.E. or S.S.W. Good sections can be seen in the burns to the west of Brae and around Loch Mhic Mharsaill. Farther south towards the Oykell–Carron watershed, on the slopes of Beinn Ulbhaidh the siliceous granulites are evenly interbedded with subordinate semi-pelitic bands. These latter, each an inch or two in thickness, owe their darker colour to the presence of abundant flakes of black mica.

Higher up on Beinn Ulbhaidh the semi-pelitic bands increase in bulk and their biotite-content becomes greater; if the ground were not so much obscured by peat it might be possible to trace a transition from the siliceous granulites into the thoroughly pelitic schist of Beinn Ulbhaidh. This pelitic schist occurs on the summit of the hill and is exposed also in the headwaters of the Allt Mòr which rise on its slopes. It is a dark-coloured, lustrous and thoroughly micaceous schist, studded with small pink garnets of the size of peas. It extends from the top of Beinn Ulbhaidh eastwards for perhaps 2 miles, while its breadth across the strike is less than a mile. On all sides the pelitic rock appears to be surrounded by the siliceous and semi-pelitic type already referred to, and is not visibly connected with the belts of pelitic schist known to occur farther to the south-west on the high ground around Carn a' Choin Deirg.

Mr. Haldane reports that the ground examined by him east and south-east of Inveroykel is largely drift-covered. Good sections are seen, however, in the numerous streams flowing N.E. and N. to the river Oykell, here tidal and called the Kyle of Sutherland. The country rock is predominantly a pale-coloured flaggy siliceous granulite, showing marked colour-banding in places. Here again the biotite-content may show a notable increase until the rock passes into a semi-pelitic type. Such semi-pelitic bands with an east to west trend occur on the east shoulder of the Coire's Airde ridge in the upper part of the Kilmachalmack Burn and on the north face of the summit of Breac Bheinn. In the south-west of the area the semi-pelitic character becomes more pronounced as the mica-schist of Beinn Ulbhaidh is approached. There is a marked absence in this ground of the granite and pegmatite veining, which is so characteristic of the country N.E. of Invershin.[1]

Well-marked mullion-structure is seen at several localities, especially in the western part of the area. The general direction of rodding is towards the south-east, parallel to the pitch of the

[1] 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, p. 45.

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folds. Fine examples of this structure are found in the Oykell at Oykell Bridge.

Igneous Rocks.—Mr. Ross reports the occurrence of two lamprophyre dykes, possibly branches of one main east-and-west intrusion, in the Allt Mòr about 300 yds. above the mouth of the Allt Fliuch Bhadain. The northern one, about a foot thick, is brick-red in colour and shows large plates of biotite. It is inclined N. 10° E. at 60 degrees. The other dyke, 100 yds. south, is parallel to the first and very similar, but contains many inclusions of schist showing rounded corners and varying in diameter from 3 to 6 inches. These inclusions are well seen on the polished dip face of the dyke, which forms the southern bank of the stream for about 30 yds. A similar lamprophyre crosses the river Einig a few yards upstream from the mouth of the Alltan Beithe, but no inclusions of schist were noted. These dykes no doubt belong to the same series of intrusions as the lamprophyres described in the 'Summary of Progress' for 1920 (p. 47), from the Invershin and Bonar Bridge district.

At Creag a' Chait, the prominent hill south-west of Achnagart, Mr. Haldane has mapped a basic rock, showing traces of shearing in places, which extends 350 yards in an east-and-west direction, and is about 30 yds. wide.

At the top of the hillside at the top of the road and about 1,000 yds. south from Creag a' Chait there are a small knob and some scattered boulders of a basic mass similar to some of the hybrid rock types found at Ach'uaine and Ledsaurich[1], 5 miles to the east.

SUTHERLAND

On the north side of the river Oykell Messrs. Macgregor, Read and Ross have mapped the ground around Altass, lower Glen Cassley, Beinn Rosail and Carn Mòr. In the western part of the area excellent sections are provided by the Allt an Leacach, the Allt Bad Air Donnadh and the Tutim Burn. The dominant rock types here are rather massive flaggy siliceous schists, frequently somewhat coarse in texture, with pebbles of pinkish felspar; in some cases these pebbles are as much as a quarter of an inch in diameter and show granulitised edges. Bands of quartzite with scattered felspar crystals occur among the flags, but rocks of a semi-pelitic or pelitic facies are conspicuously absent over most of the ground. The thin micaceous partings which locally separate the flags become thicker and more abundant however in the neighbourhood of Loch na Claise Moire and near the summit of Carn Mòr. The dip is very uniform in direction, varying slightly around S. 40° W. at angles of 30 to 70 degrees. On the higher ground, around Beinn Rosail and on Carn Mòr, the rocks are often much puckered and folded. Colour-banding is common, the darker tints being produced by varying amounts of biotite in small flakes. In Glen Cassley

[1] *Ibid.*, pp. 46–47.

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Mr. Ross finds the same rock types developed, but the pebbly character is less marked, and the flags are finely and evenly grained granulites of normal aspect. They are traversed on the east side of the glen by several crush-belts marked by breccias cemented by vein quartz. The general direction of the crush-lines is N.N.W.–S.S.E., parallel with the glen. Dips are high and mainly towards the W.S.W., but in the lower part of the Cassley valley the strike swings round into an east-and-west direction. Farthest east around Altass again the general strike is N.E.–S.W., and here Mr. Read notes that the dominant rock type is supplied by very finely flaggy beds. These are well-exposed in the Allt Mòr, a strike stream developed along a belt of fine-grained quartz-felspar-granulites separated into flags by the abundant development of large scales of white mica in parallel planes. These planes are less than an inch apart and from their regularity and extent are the cause of the remarkable topography of the Allt Mòr. The gorge of this burn is, on its south-east side(*e.g.*, the side towards the dip), defined by a vertical wall of rock, while its north-west side is an inclined *glacis* of flag planes.

On the high ground east of Glen Cassley, towards the water-shed between the Cassley and Grudie rivers, Messrs. Read and Ross find that the dominant rock type is a granulite with numerous biotite-rich bands. These striped rocks appear to occupy an area extending from Loch Doire a' Chatha N.N.E. along the strike to the neighbourhood of Carn na Ba' Maoile. The mica-rich bands are exceedingly narrow and often twelve or more of them alternate with pale quartzo-felspathic ribs in the space of an inch.

Mr. Wilson completed the mapping of the ground on the west side of Loch Shin from Salachy northwards to the boundary of one-inch sheet 102. This tract is largely covered with peat or drift and exposures of rock are few. The country-rock consists of flaggy siliceous granulites. Occasionally more massive beds composed of felspathic grits occur, and these in many instances seem to have undergone little metamorphism.

Igneous Rocks.—Messrs. Read and Ross report the occurrence of hornblendic rocks at two localities—at the waterfalls in lower Glen Cassley and in the Allt Doire a' Chatha, near the croft of Doire a' Chatha (Durcha). The rocks are essentially similar at both places. Among the different types that occur is a coarse dark-green or black rock composed almost entirely of hornblende, the acicular crystals of which show a tendency to lie with their vertical axes in one plane. In the Cassley section the rocks of this type seem to be definitely intrusive into the granulites, and at the upper falls one of these intrusions has been broken up into lenses by later movements. A slightly different type is one where the hornblendic material is banded with narrow threads of a pale-coloured felspathic substance; and by an increase in the number of such bands the rock takes on a markedly striped aspect.

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The striping is extremely delicate and persistent; it runs parallel with the foliation of the neighbouring granulite. The hornblendic layers of these striped rocks contain some greenish mica in addition and, occasionally, chlorite. Often also on the plane surfaces of the "stripes" throughout both the felspathic and hornblendic portions there are large bladed crystals of green actinolite up to 2 inches in length which lie with their vertical axes in the foliation planes but show no other orientation. A final type is represented by a rock mainly felspathic in character but with very regular, delicate and persistent bands of hornblende often less than one-twelfth of an inch in thickness. On the whole these hornblendic rocks seem to be of igneous origin; the delicate banding may be due to their heterogeneous intrusion early in the period during which the granulites received their present structure. Somewhat later the original ferro-magnesian minerals of the striped rocks were probably converted into the stress-mineral hornblende and large blades of actinolite formed upon the foliation planes.

These rocks resemble the hornblendic schists associated with the well-known Shiness Limestone.

On the south side of the River Grudie at Meall a' Ghruididh and Cnoc na Cloich-bhuaile, 3 miles W.S.W. from Lairg, Mr. Read has mapped a small mass of granite a little over a square mile in extent. It is an unfoliated coarse pink rock often showing abundant drusy cavities. The components are porphyritic pink orthoclase felspar up to half an inch in length, rounded blebs which occasionally show crystal outlines, and a few small biotite plates.

An exposure of a dark-blue, ultrabasic rock allied to scyelite was noted by Mr. Ross in a small stream flowing east into the Cassley below Glencassley Castle.

On the north-east side of Loch Shin, west of Sithean Dubh Mòr, Mr. Wilson has mapped a few small bosses of scyelitic rock similar to those previously noted by Mr. C. H. Dinham in the same district.

At two localities in Mr. Wilson's ground—Arscaig in the north, and Salachy in the south—belts of hornblende-schist occur. In both cases the rock varies in composition from nearly pure hornblende to a banded material consisting of finely striped siliceous and hornblendic layers. A search was made for the re-appearance of the Shiness Limestone at Arscaig, but without success. At the quarries at the east side of the Loch the limestone is associated with striped hornblendic rocks similar to the above, but at Arscaig the latter alone are present. Certain bands rich in epidote in the granulites may possibly represent originally calcareous layers.

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III.—PETROGRAPHICAL WORK

1. England and Wales

Petrographical work in connection with England and Wales has been carried out by Dr. Thomas chiefly in answer to enquiries from private individuals and Government departments.

An interesting post-Triassic dyke mapped by Mr. Pocock during the survey of Sheet 138, forms the subject of an appendix (p. 154).

A few rocks from Signey I. in the South Orkney Is., collected by Mr. H. E. Borge of the Tonsberg Whaling Co., and submitted for examination by the Under Secretary of State for the Colonies, are of considerable interest as they indicate the existence in that region of more ancient and more highly metamorphosed rocks than those previously collected and described from Coronation I., Laurie I., and Weddell I. The earlier collections from the South Orkneys were of relatively unaltered sedimentary rocks of presumably palæozoic age, but the specimens from Signey I. are mica-schists, foliated quartzites and metamorphic limestones. The mica-schists are dark grey well-foliated quartzose rocks composed of quartz, biotite and muscovite with porphyroblastic pink garnet. The white crystalline limestones are foliated and consist almost entirely of calcite enveloping minute well-formed crystals of diopside and less frequent actinolitic hornblende.

An investigation has been carried out for the Government Laboratory on the crystalline and optical properties of members of a series of artificial compounds that are connected with the manufacture of certain explosives.

2. Scotland

Petrographical work in connection with the forthcoming memoir on the Island of Mull (Sheet 44) has occupied the greater part of Dr. Thomas' attention during the past year. His descriptions of the rocks collected from Sheet 54 (Moor of Rannoch) have been handed to Mr. Read, who has been entrusted with the task of writing with their aid the petrographical sections of the memoir on this region.

Connected with the current Survey work Dr. Thomas has reviewed and described new material from Mull and from the islands of Iona, Tiree, etc., as well as from Ayrshire, Renfrewshire and other southern counties. The current work on Sheet 102 (Bonar Bridge) is being carried out by Mr. Read.

From Iona, Mr. Anderson has submitted for examination a suite of pelitic schists and gneisses and the associated tremolite- and forsterite-marbles known respectively as Iona marble and Silverstone. He has also collected a beautiful hornblende-eclogite composed of green hornblende, omphacite, idiomorphic pink garnets, well-formed prisms of pleochroic hypersthene, plagioclase felspar, a little fox-red biotite and quartz.

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The foliated gneisses of the Lewisian Complex of the island are mainly plagioclase-gneisses and are characteristically rich in epidote. Amongst them is a curious magnetite-bearing rock, composed almost entirely of magnetite, fibrous hornblende and garnet, which is associated with interesting types consisting of pink garnet and chlorite, and garnet and quartz.

The supposed Torridonian sediments that come within the influence of the westerly extension of the Ross of Mull granite have the characters of biotite-hornfelses and occasionally carry andalusite.

The ancient rocks are cut by a series of irregular unfoliated intrusive sheets of porphyrite, amongst which quartz-mica-porphyrites, hornblende-porphyrites and albite-porphyrites are represented.

Some of the later dykes of Iona show their similarity to others described from the Ross of Mull and the neighbouring Colonsay by their monchiquitic and lamprophyric affinities—good monchiquites and camptonites are well represented.

As a result of his work on the Lewisian Gneiss of the outlying island of Tiree, Mr. Bailey has submitted a suite of specimens (20828–20839) to illustrate the sediments, and certain closely associated rocks, of the Dun Gott exposure. The main type is a pyroxenic gneiss; but a forsterite-marble (20837), a graphite-schist (20838), and a garnet-biotite-gneiss (20834) are characteristically represented. An interesting thin seam from near the margin of the outcrop is a beautiful eclogite (20828) similar to that from Iona mentioned above. It is composed of omphacite, hypersthene, garnet, and quartz—and parts of the slide are relatively rich in pyroxene or quartz, as the case may be, and poor in garnet.

The orthogneisses of Tiree collected by Mr. Bailey include basic hornblende-schists, intermediate hornblende-biotite-gneiss, and acid quartzo-felspathic gneisses.

A quartzose orthophyre-sheet collected on the shore east of An Cnap (20845) likely belongs to the Old Red Sandstone period. Otherwise the late minor intrusions sliced vary from basalt to camptonite in composition. Good camptonites have been met with as north-west dykes, one west of Librig Mhor (20852) and another south of Poll a' Chrosain (20853). A somewhat decomposed sheet from a little island north-north-west of Miodar (20842) is also of somewhat camptonitic type. It has porphyritic crystals of pale violet augite and pseudomorphs after olivine, together with small columnar crystals of augite, cloudy oligoclase, and some brown hornblende in an alkali-felspar base; a high power shows abundant needles of apatite.

From Sheet 22 (Ayrshire), in addition to a large collection of basalts and andesites of Old Red Sandstone and Calciferous Sandstone ages, an interesting teschenitic rock has been examined from the Hillhouse Quarry. This rock varies considerably in

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texture, the coarser portions containing abundant ophitic titaniferous augite, while the finer portions are much more alkaline in character. The finer portion, which often acts as matrix to the coarser textured rock, is composed of titaniferous augite edged with ægirine, blade-like crystals of ægirine and rich yellow-brown biotite, in a base of analcite crowded with needles of apatite.

A good suite of trachytic lavas of Calciferous Sandstone age has been collected by Mr. Burnett from the neighbourhood of Moorhouse, Bannerbank, and Mid Floak in Renfrewshire. Many are typical trachytes, but others are best described as trachybasalts or trachydolerites.

IV.—CHEMICAL WORK

During the past year analyses were made of 24 igneous rocks, two of these being from Mull (for Memoir on Sheets 43, 44), and the rest from Aberdeen and Banffshire (for Memoir on Sheets 86, 87 and 96). In addition four Scotch iron ores were analysed. The results of the analyses are appended below.

For completing the work on Fireclays for the Special Report on British Refractory Materials a further eighteen analyses have been made.

The chemical and mineralogical composition of the Strathmore Meteorite has also been determined.

The following are rocks analysed for Memoir on Sheets 86, 87 and 96 :—

20322. Lab. No. 642.
Olivine-norite. Knob in front garden of New Forest, Kirkney Water, Aberdeenshire. 1 in. sheet 86. 6 in. Aberdeen 42 N.E.

20324. Lab. No. 644.
Granite. Quarry, ¼ mile S. & E. of Weets, Insch, Aberdeenshire. 1 in. sheet 86. 6 in. Aberdeen 34 S.E.

20327. Lab. No. 645.
Hypersthene-gabbro. Escarpment, ¼ mile W. of Bridgend of Shevock, Insch, Aberdeenshire. 1 in. sheet 86. 6 in. Aberdeen 44 N.E.

20328. Lab. No. 646.
Olivine-gabbro. Old Rand Pit, Bonnyton, Insch, Aberdeenshire. 1 in. sheet 86. 6 in. Aberdeen 35 S.E.

19969. Lab. No. 663.
Contaminated gabbro at edge of Insch Igneous Mass. 400 yards S. by E. of Easter Saphook, Old Meldrum. 1 in. sheet 86. 6 in. Aberdeen 45 N.E.

19906. Lab. No. 660.
Quartz-diorite of the Insch Mass. Graveyard Railway Cutting. 430 yards S.S.E. of Leith Hall, Kennethmont. 1 in. sheet 86. 6 in. Aberdeen 43 N.W.

20326. Lab. No. 661.
Quartz-dolerite. Dyke in olivine-norite, Auchinbradie Quarry, Knockenbaird, Insch. 1 in. sheet 86. 6 in. Aberdeen 44 N.W.

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19654. Lab. No. 662.
Norite of Huntly Igneous Mass, Hill of Mungo, 3 miles N.N.E. of Huntly. 200 yds. W. by N. of Summit, at wall. 1 in. sheet 86. 6 in. Aberdeen 26 N.E.

20487. Lab. No. 664.
Diorite of Huntly Igneous Mass. Knob in field on S.W. side of Craigwillie, 1 mile W. of Huntly. 1 in. sheet 86. 6 in. Aberdeen 26 S.W.

20488. Lab. No. 665.
Uncontaminated Norite of Arnage Mass. Railway cutting, 600 yds. S. of Mill of Inkhorn, Arnage, Ellon. 1 in. sheet 87. 6 in. Aberdeen 30 S.E.

20489. Lab. No. 666.
Contaminated Norite of Arnage Mass. Quarry at roadside, ½ mile N.E. of Mains of Drumwhindle Arnage, Ellon. 1 in. sheet 87. 6 in. Aberdeen 38 N.W.

20490. Lab. No. 667.
Much contaminated Norite of Arnage Mass, Carding Hill, 700 yards S.S.E. of Arnage House, Arnage, Ellon. 1 in. sheet 87. 6 in. Aberdeen 30 S.E.

20583. Lab. No. 674.
Cullen Quartzite. Shore, S.W. side of Craig Head, midway between Findochty and Portessie, Banffshire. 1 in. sheet 96. 6 in. Banff. 2 N.W.

20584. Lab. No. 675.
Micaceous bands in Cullen Quartzite. In little port on landward side of Bow Fiddle, N.E. side of Portknockie, Banffshire. 1 in. sheet 96. 6 in. Banff. 2 N.E.

20585. Lab. No. 676.
Typical Findlater Flag. Findlater Castle, 2 m. E. of Cullen, Banffshire. 1 in. sheet 96. 6 in. Banff. 3 N.W.

20586. Lab. No. 677.
Actinolite-schist. West side of Garron Point, ½ m. N.N.W. of Sandend, Banffshire. 1 in. sheet 96. 6 in. Banff. 3 N.E.

20587. Lab. No. 678.
Black Schist from Sandend Group. N. side of Sandend Harbour, Banffshire. 1 in. sheet 96. 6 in. Banff. 3 N.E.

20588. Lab. No. 679.
Durn Hill Quartzite. Durn Hill Quarry, 1 mile S.S.W. of Portsoy, Banffshire. 1 in. sheet 96. 6 in. Banff. 3 S.E

20589. Lab. No. 680.
Graphite-schist, from Portsoy Group Hythe of John Legg's Well, west side of Portsoy, Banffshire. 1 in. sheet 96. 6 in. Banff. 3 N.E.

20590. Lab. No. 681.
Cowhythe Gneiss. Strathmarchin Bay, east side of East Head, Portsoy, Banffshire. 1 in. sheet 96. 6 in. Banff. 4 N.W.

20591. Lab. No. 682
Andalusite-schist. Shore, ½ mile, E. of U.F. Manse, Whitehills, Banffshire. 1 in. sheet 96. 6 in. Banff. 4 S.E.

20592. Lab. No. 683.
Macduff Slate. At cave in Old Haven, at mouth of Burn of Melrose, 2 miles E. of Macduff, Banffshire. 1 in. sheet 86. 6 in. Banff. 5 S.W.

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Slice No.	20322	20324	20327	20328
Lab. No.	642	644	645	646
SiO_2	45·32	77·36	49·30	44·65
TiO_2	6·03	·18	3·19	3·69
Al_2O_3	14·25	10·01	14·03	17·95
Fe_2O_3	1·74	·84	·09	1·09
Cr_2O_3	nt. fd.	nt. fd.	nt. fd.	nt. fd.
V_2O_3	nt. fd.	nt. fd.	nt. fd.	nt. fd.
FeO	14·82	·56	9·61	15·02
MnO	·11	·12	·31	·36
(CoNi)O	nt. fd.	nt. fd.	nt. fd.	nt. fd.
BaO	·03	·04	nt. fd.	·01
CaO	8·80	·72	12·31	9·50
MgO	3·72	·09	6·82	3·34
K_2O	·83	5·10	·30	·54
Na_2O	2·59	3·28	2·66	2·79
Li_2O	nt. fd.	nt. fd.	trace	trace
H_2O at 105° C.	·10	·08	·11	·10
H_2O above 105°C.	·37	·26	·76	·45
P_2O_5	·74	·98	·05	·09
FeS_2	·09	nt. fd.	·08	·12
Fe_7S_8	·37	nt. fd.	nt. fd.	·12
CO_2	·31	·44	·42	·28
Total	100·22	100·06	100·04	100·10

Anal. E. G. Radley.

Slice No.	19969	19906	20326	19654	20487	20488	20489	20490	Slice No.
Lab. No.	663	660	661	662	664	665	666	667	Lab. No.
SiO_2	56·18	56·07	50·78	49·18	51·57	52·04	62·39	47·88	SiO_2
TiO_2	1·54	2·38	4·65	1·24	3·83	·66	·99	1·49	TiO_2
Al_2O_3	19·17	13·18	9·64	16·00	16·15	16·31	17·33	26·35	Al_2O_3
Fe_2O_3	·47	1·22	3·27	·02	·37	·06	·48	·95	Fe_2O_3
Cr_2O_3	nt.fd.	nt.fd.	nt.fd.	·03	nt.fd.	·05	nt.fd.	nt.fd.	Cr_2O_3
V_2O_3	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	·01	nt.fd.	nt.fd.	V_2O_3
FeO	9·84	7·47	10·72	8·02	10·39	7·98	7·19	12·01	FeO
MnO	·15	·26	·26	·20	·14	·14	·18	·18	MnO
(CoNi)O	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	(CoNi)O
BaO	·09	·14	·01	trace	·02	trace	·03	·01	BaO
CaO	2·16	7·01	9·62	12·54	6·94	7·24	2·10	2·91	CaO
MgO	2·97	4·87	5·12	9·47	4·96	11·70	2·81	2·87	MgO
K_2O	2·61	2·44	·70	·26	·93	·89	·48	1·31	K_2O
Na_2O	1·71	2·79	2·31	2·04	2·69	1·82	3·41	1·75	Na_2O
Li_2O	trace	trace	nt.fd.	trace	trace	trace	nt.fd.	trace	Li_2O
H_2O at 105° C.	·28	·12	·77	·07	·08	·06	·11	·23	H_2O at 105° C.
H_2O above 105° C.	1·85	·90	·86	·41	·61	·51	1·47	1·32	H_2O above 105° C.
P_2O_5	·09	·23	·21	·10	·46	·08	·22	·32	P_2O_5
FeS_2	·28	·14	·02	·02	·06	·02	·05	·23	FeS_2
Fe_7S_8	·49	·22	·31	·37	·50	·51	·58	·16	Fe_7S_8
CO_2	·15	·63	·80	·33	·48	·46	·42	·23	CO_2
Total	100·03	100·07	100·05	100·30	100·18	100·54	100·24	100·20	Total.

Anal. E. G. Radley.

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Slice No.	20583	20584	20585	20586	20587	20588	20589	20590	2059
Lab. No.	674	675	676	677	678	679	680	681	682
SiO_2	86·12	60·70	66·33	54·44	60·95	96·58	44·83	67·23	53·9
TiO_2	·39	1·32	·99	1·05	1·17	trace	1·05	·86	1·1
ZrO_2	·03	·05	—	—	—	·01	—	—	—
Al_2O_3	5·72	19·79	16·92	13·17	16·00	1·62	28·67	13·38	22·77
Fe_2O_3	·75	3·63	1·70	1·26	4·37	·59	6·29	1·23	2·33
FeO	·61	3·63	3·41	4·14	—	·11	—	4·88	7·22
MnO	·17	·18	·21	·17	·21	·03	·24	·16	·18
(CoNi)O	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.	nt.fd.
BaO	nt.fd.	·08	·15	·04	·03	nt.fd.	·05	·04	·12
CaO	·85	·68	1·16	6·54	3·02	·21	·33	2·08	1·97
MgO	·04	·98	1·21	13·34	2·97	·02	3·49	4·33	3 16
K_2O	3·15	6·44	5·34	3·12	2·40	·61	6·39	2·92	2·97
Na_2O	1·44	·42	1·57	·48	2·93	trace	·97	1·92	2·14
Li_2O	nt.fd.	nt.fd.	trace	nt.fd.	nt.fd.	trace	nt.fd.	nt.fd.	nt.fd.
H_2O at 105°C.	·09	·18	·04	·18	·34	·01	·47	·05	·10
H_2O above 105°C.	·27	1·70	·85	·76	1·62	·15	4·34	1·03	1·87
P_2O_5	·03	·15	·16	·24	·12	·03	·16	·15	·17
FeS_2	nt.fd.	nt.fd.	nt.fd.	nt.fd.	2·57	nt.fd.	1·51	·01	nt.fd.
Fe_7S_8	—	—	—	—	—	—	—	·07	nt.fd.
CO_2	·42	·22	·11	1·44	·09	·23	·04	·11	·04
C	—	—	—	—	1·44	—	1·26	—	—
Total	100·08	100·15	100·15	100·37	100·23	100·20	100·09	100·45	100·17

Anal. E. G

The following are analyses for Memoir Sheets 43 and 44

20581. Lab. No. 669. Tholeiitic Olivine-basalt.

Shore cliff at Rudha na h-Uamha, S. of the Wilderness, Ardme Mull. 1 in. sheet 43. 6 in. Argyll. 105 N.E.

20582. Lab. No. 670. Typical Mugearite.

Southward continuation of Ben More Mugearite Lava. Below 290 yards E. of Kinloch Hotel, Mull. 1 in. sheet 44. 6 in. Argyll. 9

Slice No.	20581	20582
Lab. No.	669	670
SiO_2	49·76	55·76
TiO_2	·94	1·78
Al_2O_3	14·42	16·55
Fe_2O_3	3·95	3·10
FeO	7·77	6·02
MnO	·20	·22
(CoNi)O	nt. fd.	nt. fd.
BaO	·04	·07
CaO	10·22	3·23

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Slice No.	20581	20582
Lab No.	669	670
MgO	5·30	1·08
K_2O	1·83	3·87
Na_2O	2·49	6·28
Li_2O	trace	trace
H_2O at 105° C.	2·04	·80
H_2O above 105° C.	1·03	·95
P_2O_5	·21	·40
FeS_2	·04	nt. fd.
CO_2	·06	·03
Total	100·30	100·14

Anal. E. G RADLEY.

Scotch Iron Ores.

20740 Lab. No. 685.

Garnet Magnetite Rock.—Crystals of Magnetite in a matrix of garnet and opalescent quartz.

Vertical band in Lewisian Gneiss. Opposite Eilean Musimul on S. coast of Iona.

20737. Lab. No. 686.

Magnetite Rock.—Rock composed of magnetite, fibrous hornblende, tremolite, pink garnet, and secondary quartz.

Irregular dissemination in Lewisian Gneiss. Just W. of Port an Fhir-bhreige, on S. coast of Iona.

Slice No.	20740	20737
Lab. No.	685	686
Total Iron	29·40 per cent.	29·68 per cent.

Sulphur and Phosphorus present only in small amounts.

Anal. F. R. ENNOS.

Lab. Nos. 691A and 691B.

Two portions of seam of Ironstone between beds of baked shale and igneous sheets. On shore below H.W.M. 1½ m. 353 yds. W. 23° S. of Kilchoan landing jetty, and ½ m. 78 yds. W. 6° N. of trigonometrical station on Maol Buidhe, Kilchoan, Ardnamurchan. 1 in. sheet 51. 6 in. Argyll. 24 S.W. (*see* p. 97).

Lab. No. 692.

Portion of seam of Ironstone. Just below H.W.M. ¾ m. 180 yds. S.42° W. of Kilchoan landing jetty and 700 yds. E. 13° N. of trigonometrical station on Maol Buidhe, Kilchoan, Ardnamurchan. 1 in. sheet 51. 6 in. Argyll. 24 S.E. (*see* p. 97).

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Lab. No.	691A	691B	692
SiO_2	30·15	17·07	7·73
TiO_2	·33	·42	·16
Al_2O_3	7·89	11·08	3·53
Fe_2O_3	12·20	23·40	·03
FeO	16·73	7·22	4·75
MnO	·53	·67	1·08
(CoNi)O	·06	·05	nt. fd.
BaO	nt. fd.	nt. fd.	nt. fd.
CaO	24·57	25·79	43·49
MgO	3·56	3·88	1·41
K_2O	·28	·28	·26
Na_2O	·41	·45	·42
Li_2O	nt. fd.	nt. fd.	nt. fd.
H_2O at 105° C.	·19	·14	·36
H_2O above 105° C.	·94	1·62	1·20
P_2O_5	1·43	1·90	1·90
FeS_2	·22	·16	4·71
Fe_7S_8	nt. fd.	nt. fd.	·58
CO_2	·99	6·35	28·57
Total	100·48	100·48	100·18

Anal. E. G. Radley.

V.—PALÆONTOLOGICAL WORK

1. England and Wales

The valuable collection of Jurassic Mollusca from the Hudleston collection, presented during the previous year by Miss C. A. Raisin, has been supplemented by a further gift from the same donor. This is a suite of 50 choice invertebrate fossils of a miscellaneous character selected from Miss Raisin's collection.

A study of the Hudleston collection by Mr. C. P. Chatwin showed the necessity for a re-examination of the Kimmeridge and Portland succession at Swindon. Mr. Chatwin and Mr. J. Pringle have paid visits to that locality and have added considerably to our knowledge of the zones represented there. They were successful in establishing the presence of the Rasenia and Gravesia Zones of the Kimmeridge Clay, which Dr. Salfeld had been unable to record. They have also shown that the fauna of the so-called Portland Sands, which there includes many uncrushed ammonites, belongs in reality to the upper part of the Virgatites Zone, thus confirming the suggestion of the late H. B. Woodward that the overlying Swindon Clay is comparable with the Hartwell Clay of Aylesbury. An account

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of their investigation is published herewith as an Appendix (p. 162).

Information obtained by Mr. Pringle before and during the war respecting the important deep boring at Westbury, Wiltshire, has now been made available for publication, and forms the subject of another Appendix (p. 146).

Additional specimens from the deep boring at Great Marlow have been received and examined during the year. It was found that the Lower Greensand there rests on the Oxford Clay, which was penetrated by the boring to a depth of 32 ft. The clay was highly fossiliferous and yielded ammonites and other fossils which Mr. Pringle found to be characteristic of the Renggeri Zone, the middle part of the Oxford Clay. He states that the fauna is practically identical with that obtained from the clay recovered from the chisels at the depths of 1,026 ft. and 1,032 ft. in the Little Missenden boring. The presence of the Oxford Clay in the Great Marlow boring lends strong support to the view that the clay penetrated below the Lower Greensand in the Maidenhead boring also belongs to the same Jurassic formation.

A boring for water at Old Gate, east of Sutton Crosses near Long Sutton, Lincolnshire, was visited by Mr. Pringle and proved to be of much interest. Under a cover consisting of 55 ft. of yellow sand underlain by 140 ft. of grey boulder-clay with flints and chalk-pebbles, Jurassic clays were penetrated. These were proved to a thickness of 106 ft. and were shown by the evidence of fossils to belong to the lower part of the Ampthill Clay and to the Oxford Clay down to its middle portion. This fact throws some light on the position of the western boundary of the Kimmeridge Clay under the superficial deposits of the Wash.

New quarrying operations initiated by Col. A. Arthur Lyle at Barrington, Somerset, have provided an opportunity to study afresh the sections in the Lias of that neighbourhood made classic by the researches of Charles Moore some 50 years ago. Prof. D. M. S. Watson visited the openings and drew attention to the interest of the sections disclosed. Mr. Pringle and Mr. A. Templeman visited Barrington and obtained full details of the Middle and Upper Lias succession. Exhaustive zonal collecting was carried out by Mr. Templeman, and it became possible to ascertain the exact horizon of Moore's principal fossil-beds within a stratigraphical scale based on ammonite-classification. The highest of the strata attributed by Moore to the Middle Lias are found to fall at the basal part of the Upper Lias, in the Tenuicostatum Zone. Numerous fine specimens of the genus *Harpoceratoides* were obtained from the beds above the Exaratum Zone, and it has been found practicable to establish a new and well characterized zonal unit. A complete study of the fossils from these quarries will afford much help in correlating the Upper Lias deposits of this neighbourhood with those of Oxfordshire and other Midland counties.

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Dr. Kitchin and Mr. Pringle visited localities in Oxfordshire, Buckinghamshire and Bedfordshire, obtaining particulars of exposures in the Upper Jurassic rocks and in the Lower Greensand and Gault. Under Mr. S. S. Buckman's guidance they examined an old brick-pit on the Thame Park estate near Thame, situated about one-third of a mile S.S.W. of the railway station. The pit lies within the area coloured as Gault on the geological map, near its junction with the Lower Greensand as represented on the map (Old Series, Sheet 13). The exposures showed a series of fine white-weathering silty clays with a layer of large bluish-grey nodules. The clays appeared to be of estuarine or fresh-water origin. Excepting a few doubtful plant-fragments, no fossils were seen. These beds are considered to represent some portion of the Shotover Sands and are probably of early Wealden age. Excavations in progress in an adjoining field to the north showed the presence of sands belonging to the Portland series. There was no evidence for the outcrop of Lower Greensand shown on the geological map. At the disused Priest End brick-pit, south-west of Thame, the Gault appeared to rest directly on Portland Sands.

At Towersey, east of Thame station, a well and other new excavations gave evidence that the Gault there rests on Purbeck Beds. The lower part of the Gault showed the brecciated character noticed in the lowest part of the overlapping Upper Gault north of Leighton Buzzard. During a visit to the Leighton Buzzard neighbourhood, further evidence was obtained for the overlap of the Upper Gault north of that town.

Mr. Pringle visited Gillingham, Dorset, and examined the Kimmeridge Clay exposed in the large clay-pit near the railway-station. He was able to determine the exact zonal range of the clays exposed in this section. They belong to the upper part of the *Rasenia cymodoce* Zone and the lower part of the overlying *Rasenia mutabilis* Zone. An account of this pit will appear in the forthcoming Memoir on Sheet 313.

Work has been continued in the registration of the Museum collection. Mr. Chatwin has devoted further attention to the collection of Tertiary Mollusca; he has also selected from reserve stores and has registered and named extensive suites of fossils from the Corallian, Kimmeridge and Portland rocks for incorporation in the Museum. This is in preparation for a revision and rearrangement of the cases illustrating those formations. The new materials thus to be utilised are contained in the Hudleston collection and in the additional set of fossils presented by Miss Raisin.

Efforts have been made to find satisfactory methods of preserving pyritized fossils. Mr. S. W. Morgan has treated a large number of specimens with various preservative solutions and has kept full records of these experiments.

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The following specimens in the Museum have been figured, described or mentioned in publications :—

IN THE PALÆONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1919. (PUBLISHED 1921.)

A Monograph of the British Ordovician and Silurian Bellerophontacea. (Part ii.)

By DR. F. R. COWPER REED, M.A.

Tremnodiscus fletcheri *Reed*, pl. ix, fig. 6, p. 48.
" murchisoni (*d'Orb.*), pl. ix, figs, 8, 8a, b, 9, 9a, p. 49, (2 specimens).
Bellerophon ledburiensis *Reed*, pl. ix, figs. 14, 14a, p. 56.
Bucaniopsis expansus (*J. de C. Sow.*), pl. x, figs. 1, 1a, 2, p. 60, (2 specimens).
Cymbularia alata (*Portl.*), pl. x, figs. 10, 11, p. 63, (2 specimens).
" carinata (*J. de C. Sow.*), pl. x, figs. 12, 13, 14, p. 66, (3 specimens).
" *cf.* fastigiata (*Lindström*), pl. xi, figs. 11, 11a, 12, p. 70, (2 specimens).
Salpingostoma ? infundibulum *Reed*, pl. xii, fig. 5, p. 78
Trematonotus aymestriensis (*J. de C. Sow.*), pl. xii, figs. 7, 8, 8a, p. 79, (2 specimens).
" dilatatus (*J. de C. Sow.*), pl. xiii, fig. 1, p. 80.
" portlocki *Reed*, pl. xiii, figs. 4, 4a, b, p. 83.
Zonidiscus sp., p. 74, (3 specimens).

A Monograph of the Fossil Insects of the British Coal Measures. (Part i.)

By MR. H. BOLTON, M.Sc., F.R.S.E.

Orthocosta splendens *Bolton*, pl. i, figs. 2a, b; text-fig. 1, p. 28, (2 specimens).
Pteronidia plicatula *Bolton*, pl. i, figs. 3a, b; text-fig. 2, p. 30, (2 specimens).
Cryptovenia moyseyi *Bolton*, pl. ii, figs. 1a, b; text-fig. 4, p. 36, (2 specimens).
Boltoniella tenuitegminata (*Bolton*), pl. iii, fig. 4, p. 56.
Pseudofouquea cambrensis (*Allen*), pl. iv, fig. 8a; text-fig. 22, p. 73.

The Pliocene Mollusca of Great Britain. Volume II. (Part ii).

By MR. F. W. HARMER, M.A.

Acrybia smithi (*Brown*), pl. lv, fig. 9, (2 views), p. 699.
Natica multipunctata *S. V. Wood*, pl. lv, fig. 12, (2 views), p. 677.

IN THE QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY, VOLUME LXXVI.

The Cambrian Horizons of Comley (Shropshire).

By MR. E. S. COBBOLD.

Micromitra (Paterina) phillipsi *Holl.*, pl. xxi, figs. 1, (2 views), 2, (3 views), p. 329, (2 specimens).
" " rhodesi *Cobbold*, pl. xxi, figs. 4a, b, c, 6, (2 views), p. 330, (2 specimens).
" " kingi *Cobbold*, pl. xxi, figs. 7, (2 views), 8a, b, p. 330, (2 specimens).

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Micromitra (Paterina) minor *Cobbold*, pl. xxi, fig. 15, p. 333.
„ „ „ *var.* gibbosa *Cobbold*, pl. xxi, fig. 17, (2 views), p. 334.
„ sp., pl. xxi, fig. 9, (3 views), p. 330.
Walcottina lapworthi *Cobbold*, pl. xxi, figs. 23a-c, 24a, b, 25, p. 336 (2 specimens).
Obolus ? linnarssoni *Cobbold*, pl. xxii, fig. 23, p. 338.
Lapworthella nigra *Cobbold*, pl. xxiv, figs. 1, 3, 4, p. 360, (3 specimens).
Scenella elevata *Cobbold*, pl. xxiv, fig. 36, (2 views), p. 364.
Escasona ? spp., pl. xxiv, figs. 47, (3 views), 48, (3 views), p. 368.
Leperditia ? dermatoides *Walcott* (?), p. 368.

In the Quarterly Journal of the Geological Society, Volume LXXVII.

A New Species of Blattoid (Archimylacris) from the Keele Group (Radstockian) of Shropshire.

By Mr. H. Bolton, M.Sc., F.R.S.E.

Archimylacris pringlei *Bolton*, pl. i, figs. 1, 2; text-fig. 1, p. 24, (2 specimens)

The Evolution of certain Liassic Gasteropods, with special reference to their Use in Stratigraphy.

By Miss A. I. McDonald, M.Sc., and Dr. A. E. Trueman.

Katosira trivia (*Tate*), pl. xxii, fig. 2, p. 335.
Promathildia tenuicostata (*Portl.*), pl. xxii, fig. 6, p. 336
„ ligaturalis (*Tate*), text-fig. 23, p. 338.
Procerithium liassicum (*Tate*), text-fig. 6b, p. 307.
„ dayi (*Tate*), p. 314.
„ raricostati (*Tate*), p. 314.
„ subfistulosum (*Tate*), text-fig. 10, p. 320.
Zygopleura nuda (*Tate*), text-fig 16, p. 329.
„ semitecta (*Tate*), text-fig. 20, p. 332.
Bourguetia deshayesea (*Terquem*), p. 339

In the Geological Magazine, Volume LVIII.

Notes on the Fauna of the Lower Devonian of Torquay.

By Dr. F. R. Cowper Reed, M.A.

Stropheodonta murchison (*d'Archiac and de Verneuil*), p. 314.
„ gigas (*M'Coy*), p. 315, (2 specimens).
Chonetes plebeia *Schnur*, p. 316, (6 specimens).
„ sarcinulata (*Schloth.*), p. 316.
Camarotœchia daleidensis (*Roemer*), p. 317, (4 specimens).
Tropidoleptus rhenanus *Frech*, p. 321, (10 specimens).

In Proceedings of the Geologists' Association, Volume XXXII.

On the Beds at the Base of the Ypresian (London Clay) in the Anglo-Franco-Belgian Basin.

By Dr. L. Dudley Stamp.

Melanopsis ancillaroides *Desh.*, pl. 2, fig. 8, p. 97.

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In Type Ammonites, Volume III., 1920–1921.

By Mr. S. S. Buckman.

Korythoceras korys *S. Buckm.*, p. 17, (2 specimens).
Pavloviceras omphaloides (*J. Sow.*), pl. cxcv, figs. 1, 2, 3, 3a, p. 18, (2 specimens).
Sagitticeras sagitta *S. Buckm.*, pl. cclx, p. 19.
Proplanulites majesticus *S. Buckm.*, pl. ccxxvi, figs. 1, 2, p. 34.
„ basileus *S. Buckm.*, pl. cclii, figs. 1, 2, p. 34.
„ laevigatus *S. Buckm.*, pl. ccxxxii, figs. 1, 2, p. 34.
„ sp., p. 34.
„ ferruginosus *S. Buckm.*, p. 34.
„ opimus *S. Buckm.*, p. 35, (2 specimens).
„ *aff.* arciruga (*Tornquist*), p. 35, (2 specimens).
„ polonicus *S. Buckm.*, p. 35.
„ occultus *S. Buckm.*, p. 35.
„ latus *S. Buckm.*, p. 35.
„ koenigi (*J. Sow.*), p. 36, (3 specimens).
„ laboratus *S. Buckm.*, p. 36.
„ involutus *S. Buckm.*, p. 36, (4 specimens).
„ lentus *S. Buckm.*, p. 36.
„ subcuneiformis *S. Buckm.*, p. 37, (2 specimens).
„ auriculatus *S. Buckm.*, p. 37, (2 specimens).
„ capistratus *S. Buckm.*, pl. ccxiii, figs. 1, 2, p. 37, (2 specimens).
„ rudis *S. Buckm.*, p. 37, (3 specimens).
„ arciruga (*Teisseyre*), p. 38.
„ oidaleus *S. Buckm.*, p. 38, (3 specimens).
„ stiphrus *S. Buckm.*, p. 38, (2 specimens).
„ petrosus *S. Buckm.*, p. 38.
„ lyprus *S. Buckm.*, p. 38, (2 specimens).
„ tridens *S. Buckm.*, p. 38.
„ excentricus *S. Buckm.*, p. 39, (2 specimens).
„ partitus *S. Buckm.*, p. 39.
„ rufus *S. Buckm.*, p. 39.
„ fulvus *S. Buckm.*, p. 39, (2 specimens)
„ fracidus *S. Buckm.*, p. 40, (2 specimens).
„ capularis *S. Buckm.*, p. 41, (2 specimens).
Crassiplanulites crassicosta *S. Buckm.*, pl. ccxxviiiA; pl. ccxxviiiB, figs. 1, 2, p. 42.
„ crassiruga *S. Buckm.*, pl. ccliii, p. 42.
Tulites subcontractus (*Morris and Lycett*), p. 45.
Madarites madarus *S. Buckm.*, p. 46.
„ glabretus *S. Buckm.*, p. 52.
Bullatimorphites bullatimorphus *S. Buckm.*, p. 47.
Morrisites morrisi (*Oppel*), p. 49.
Gowericeras metorchum *S. Buckm.*, pl ccliv, figs. 1, 2.

In Jahresbericht (7) des Niedersächs. geol. Ver. zu Hannover (Geol. Abteil. der Naturhist. Gesellsch. zu Hannover), 1914.

Ueber einige stratigraphisch wichtige und einige seltene Arten der Gattung Perisphinctes aus dem oberen Jura Nordwestdeutschlands.

By Prof. Hans Salfeld, Ph.D.

Perisphinctes *cf.* biplex (*J. Sow.*), p. 241.
„ wartae *Bukowski*, p. 249, (3 specimens).

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IN ZEITSCHR. DER DEUTSCH. GEOL. GESELLSCH., VOLUME LXVII., JAHRG. 1915.

Monographie der Gattung Cardioceras Neumayr et Uhlig. Teil i, Die Cardioceraten des oberen Oxford und Kimmeridge.

By PROF. HANS SALFELD, Ph.D.

Cardioceras prae-bauhini *Salfeld*, pl. xvii, figs. 5a, b, p. 179.
" serratum (*J. Sow.*), pl. xviii, figs. 1a, b, c, 2a, b, p. 172, (4 specimens).
" cricki *Salfeld*, pl. xix, figs. 3a, b, c,—6a, b, c, p. 191, (4 specimens).
" kitchini *Salfeld*, pl. xix, figs. 8a, b, c,—17a, b, c, p. 189, (10 specimens).

IN PALÆONTOGRAPHICA, VOLUME LXII., STUTTGART, 1917.

Monographie der Gattung Ringsteadia (gen. nov.).

By PROF. HANS SALFELD, Ph.D.

Ringsteadia anglica *Salfeld*, pl. xiii, p. 76, (3 specimens).
" pseudo-cordata (*Blake*), p. 80, (2 specimens).

2. SCOTLAND.

The materials accumulated during the year were chiefly dealt with by Dr. G. W. Lee in the Survey Office, but as in previous years the Ammonites have been submitted to Mr. S. S. Buckman and the Carboniferous Plants to Dr. R. Kidston. Prof. A. C. Seward has furnished a report on Tertiary Plants collected during a previous year in Mull.

The Carboniferous fossils examined by Dr. G. W. Lee have revealed some interesting points. A large and varied collection made by Mr. Manson in the Douglas district shows the presence of faunal assemblages having the features of the faunas which elsewhere characterise respectively the Hollybush Limestone, the Blackbyre Limestone, and the shale associated with the Blackhall Limestone. Opportunity may be taken here of mentioning the discovery of a remarkable fossil, which is not only new to the Scottish Carboniferous rocks, but is probably also new to science. It is an astreiform coral whose external characters are curiously like those of the Lower Palaeozoic genus *Syringophyllum*. Only one specimen is known, obtained from the core of a boring through the Upper Limestone Series, near Lenzie.

The examination of the Scottish Mesozoic Rocks has been continued, and Mr. S. S. Buckman is still engaged upon the critical study of the large number of ammonites collected from the classical localities of the north-east coast. A puzzling statement in Judd's account of the Liassic sequence in Tobermory, Mull, has now been elucidated; his reference to "*Ammonites oxynotus*" is probably due to the mistaken identification of some other discoid ammonite—perhaps a *Tragophylloceras* of the Ibex Zone. The Tobermory sequence therefore does not begin as low down as Judd thought.

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Dr. G. W. Lee identified an outcrop of the Raasay Ironstone in Ardnamurchan by finding the typical fauna of *Harpoceras*, *Dactylioceras*, and Belemnites (*see* p. 97).

VI.—MUSEUM OF PRACTICAL GEOLOGY

Considerable progress has been made in the organisation and expansion of exhibits. The Geology of the London District is now illustrated by suitable specimens and a model, recoloured to correspond with the latest 6-inch geological maps, whilst cases of specimens showing the uses of refractory materials, sands, clays and cements are now on exhibition. Exhibits to show the results of recent Survey work have been planned and are in course of development.

In the Mineralogical Department the work of investigating the petrology of the British iron ores has made considerable progress and cases have been arranged to illustrate various 'Special Reports.' Additions have been made to the collection of gemstones with a view to bringing it up-to-date.

Revision-work in the collections has made good progress, and a considerable amount of registration and re-organisation of the older collections has been accomplished.

The public have continued to use the collections, the Library and the Map Room in increasing numbers and a large amount of time has been devoted to dealing with enquiries.

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APPENDIX I

The Retreat of the Lake District Ice-Cap in the Ennerdale Area, West Cumberland

By E. E. L. Dixon, B.Sc., A.R.C.Sc.

INTRODUCTION

Gilbert, Tarr and others have described the deposits that are being built up at the front of stationary ice-sheets, such as those of Alaska, where subglacial streams emerge and cast down their overload of gravel and sand. The coarse material accumulates in masses that are banked against the ice behind, and slope down forward and laterally to a more or less lobate margin. On land the masses are fans, characterized by a uniform slope from summit (at the mouth of the stream) to margin. Those laid down under water are deltas with the gently-sloping top and the steeply-sloping front, or 'foreset' beds, usual in deltas. The masses that have survived a retreat of the ice often retain 'back' or 'ice-contact' slopes that are noticeably steep where they have been supported by a steep ice-front.

Similar fans and deltas have been recognised in the Pleistocene Drift of Europe, notably Scandinavia, and of America, in the course of the work of de Geer and of a number of American geologists. They have been variously named. Being frontal deposits, they together with certain irregular mounds and ridges of gravel and sand are all grouped by some as kames. As, however, they mark the outlets of definite and persistent subglacial streams they may usefully be distinguished from other kames and will here be spoken of as outwash-fans and outwash-deltas. In America, for deposits of either class that are "associated with an esker or esker-like chain made in the ice-sheet at the same time," Woodworth[1] has used the term 'esker-fans.' As these may evidently, from their descriptions and figures, be exactly parallelled here and the term implies the close relation with the eskers (called 'feeding-eskers' in America), it will be adopted, but for fans only; those outwash-deltas with which an esker in the position of a feeding-esker has been preserved will be called esker-deltas. Other names that have been used for either or both classes with or without related eskers, such as 'sand-plains,' 'apron-plains,' 'wash-plains,' are unsuitable for the Cumbrian examples, and the same may be said of de Geer's term 'marginal terraces' (Randterrasser)[2] for outwash-deltas.

As eskers have been the subject of much controversy it may be remarked that the few examples found near Ennerdale make wide angles with the supposed trends of the ice-front and appear to mark the courses of subglacial streams. Similar, but more

[1] *Bull. Essex Inst., Salem*, vol. xxix, 1898, p. 79.

[2] *Geol. Foren. Forh., Stockholm*, bd. 31, 1909, p. 554; *ibid.*, bd. 44, 1922, tav. I.

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definite, evidence is yielded at Newport, Salop,[1] though it is not suggested that all eskers are of this nature. However, now that such eskers are regarded by many as formed at or near the ice-front during periods of steady retreat, the distinction between kames and eskers would appear to resolve itself largely into one of elongation along or across the ice-front, dependent on rapidity of retreat.

The dip of the gravels is seldom seen. In Kelton Head out-wash-fan, which, owing to its elongation might be termed an esker, it is parallel to the steep side of the ridge.

Other deposits of use in unravelling the conditions of ice-retreat near Ennerdale are the deltas, now left on the hillsides, but originally thrown down by glacier-fed streams in bodies of standing water. The forms and the uniformity of height sufficiently show that these masses of gravel are deltas. Some of them have been referred by Prof. A. H. Green[2] to a period of marine submergence, a view supported by Prof. Gregory[3] to whom I am indebted for pointing out Green's account. But it is known that during the Glacial period the Irish Sea has been occupied by a great ice-sheet, which has invaded the Cumbrian coastal plain, and, as Mr. B. Smith shows,[4] has risen high against the fells behind the plain, impounding lakes in the dales similar to the classic examples of Glen Roy and Cleveland described by Jamieson and Prof. Kendall. That the Ennerdale deltas have been deposited in such a lake is demonstrated by the discovery of an overflow-channel at the same height as that of one set of deltas. Further, none of the gravels have yielded marine organisms; and the probable variations in height of the lake-level can be correlated with known movements of the Irish Sea ice.

Laminated clays, like those of glacier-lakes, occur in Ennerdale, but terraces and notches or old lake-cliffs are poorly developed. The burden of proof that lower Ennerdale to a height of 800 ft. above O.D. has been under water rests on the presence of deltas.

PHYSICAL FEATURES

The ground examined is the greater part of that shown on the map (Fig. 5). Around the present Ennerdale Water and in its higher reaches Ennerdale is a deep, steep-sided, rock-walled and U-shaped valley. Lower Ennerdale, *i.e.*, the valley of the Ehen, which drains the lake, is much wider, is mantled with drift, and its northern side is comparatively low; but still it contrasts strongly with the wide, gentle slopes of the northerly draining Marron valley, which commences immediately to the north. Thus there is a great right-angled re-entrant in the front of

[1] 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, pp. 19, 20.

[2] 'Physical Geology,' ed. 3, 1882, p. 633, fig. 224.

[3] *Geol. Mag.*, 1922, p. 37.

[4] *Quart. Journ. Geol. Soc.*, vol. lxviii., 1912, pp. 412, 423–44, 447.

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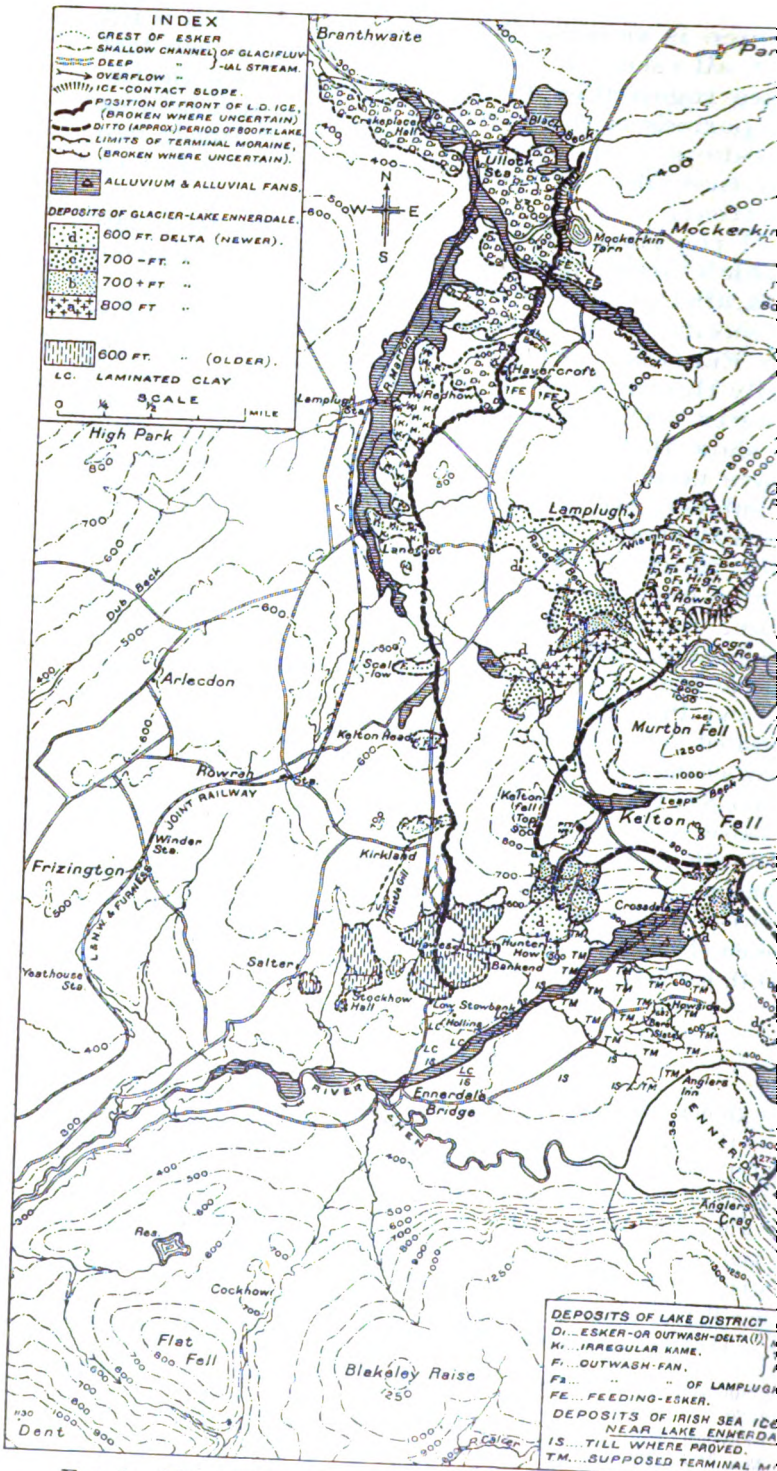

FIG. 5.—*Map showing Stages in the Retreat of the Lake District Ice-Co in the Ennerdale Area.*

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the fells, with its point at the lower end of Ennerdale Water. Running west is the high southern side of the Ehen valley, while northward extend the fells bordering the Marron valley. In this re-entrant were imprisoned the waters of glacial Lake Ennerdale, the forerunner of the present lake.

THE OUTWASH-FANS AND SUPPOSED OUTWASH-DELTAS

Most of these deposits occur in a belt of kames that has been traced from Kirkland to Mockerkin Tarn, but the finest example of an outwash-fan rises behind Lamplugh. All these kames, and also the deltas of the glacial lake, consist so largely of slate-gravel that they doubtless were formed by waters from the Lake District ice-cap. They contrast with the gravels, found in parts of the district, from the melt-water of the Irish Sea ice, in which Coal Measures debris, notably Whitehaven Sandstone, and New Red breccia are always predominant. Though the former include in places Coal Measures material, the quantities are insignificant.

The Mockerkin Tarn–Kirkland Kame-Belt.–From Mockerkin Tarn to Lanefoot the deposits are almost continuous and appear to have been subaqueous, as they have steep fronts and fairly flat tops at a height of about 400 ft. above O.D. Most have been formed by persistent streams. These are doubtfully called deltas ('esker- or outwash-deltas?') on the map because the existence of water standing at that level at the time of their formation has not yet been confirmed, and their flat tops might possibly be the result of later submergence.

The masses that have most clearly been formed at an ice-front are the two northernmost, at Mockerkin Tarn and between Snary and Todhole Becks. These are bounded on the east by steep, aligned slopes, which are inferred to be ice-contact slopes, running N. and S. parallel with the trend of the kame-belt. Their other margins are lobate. Like the sand-plains of New England and similar formations elsewhere, their tops are pitted with kettle-holes. At Mockerkin Tarn a short steep-sided esker (FE, Fig. 5) runs almost at right angles to the ice-contact slope, its top level with the top of the kame, in which it expands and is immediately lost. Evidently it corresponds, in its relations to the kame, to the 'feeding-eskers' of New England and other places, and the kame is either an 'esker-delta' or an 'esker-fan.'

Mockerkin Tarn lies in the low ground at the angle between the feeding-esker and the ice-contact slope, presumably therefore in the space left by the melting-ice. The Tarn now has no visible outlet, but formerly its level has been much higher and its overflow has cut a narrow deep channel through the ice-contact slope and straight across the kame in a S.W. direction, down to within a few feet of its present level.

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Westward from the ice-contact slope the kame narrows as far as Ullock, where it appears to end. Probably the kame was not cast forth wholly from an ice-front along its eastern margin, but during slow retreat while the front was crossing the ground between Ullock and Mockerkin Tarn.[1] Thus we may explain also the elongation, at right angles to the supposed trend of the ice-front, of many of the kames to the south, and especially the relations of an esker to the kame between Snary and Todhole Becks. This esker is a narrow steep-sided ridge that commences as a spur of the kame and runs out westward clear of the main mass. A sharp zig-zag bend in its crest (indicated on Fig. 5 by a dotted line) links it with many typical eskers, but its position is that of a distributary of the kame. It was deposited, apparently, as the ice-retreat was slowing up for the stand at the Mockerkin Tarn line.

From Lanefoot to Kirkland there are merely three small ridges running east and west, at Scallow, Kelton Head and Kirkland. These, however, are in line with the kames to the north, and in the other direction, beyond Kirkland, we find the evidence cited later of the former existence of a N. to S. ice-front. The Kelton Head ridge has the same form as some of the outwash-fans near Newport, Salop. It is pointed-oval in plan, highest at the point (eastern end) where it terminates in a steep slope, the ice-contact slope, and it spreads as it falls gradually westward. The westward fall of the other ridges is less regular. All three are concluded to be outwash-fans, in their elongation approaching eskers.

The Lamplugh Outwash-Fan.—This unusually well-developed fan (F 2) stands at the foot of the fells above Lamplugh, where the two deep valleys of the Wisenholme and Rakegill Becks emerge on the western plain, Its summit at High Hows stands at over 1,000 ft. at the top of a long north-western slope which rises from below 700 ft. on the plain, with an average gradient of 1 in 7. The south-eastern slope is much steeper (1 in 3) but shorter; it is half a mile wide (from N.E. to S.W.) and near High Hows over 100 ft. high. It is partly the side of a knoll of slate on which the half-cone of gravel has been dumped, but it is as steep where made of gravel as where made of slate.

Form, position and height. and the nature of its material show that this foot-hill is not a moraine of former valley-glaciers in the valleys of the becks—it can have been built up only as the fan of a great subglacial stream debouching at High Hows at a height of at least 1,000 ft. from a wall-like N.W.-facing ice-front (not shown on map). The south-eastern slope is the ice-contact slope, and the steady fall of the north-western slope

[1] The gravels between Ullock and Branthwaite, though lettered D_1 on the map like the kame, have been found, since the map was made, to belong to an entirely different and later, series (not shown elsewhere on the map) extending down the Pardshaw valley and the Marron below Ullock.

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indicates subaerial conditions of deposition at least as low as 700 ft.

The height of the ice-front and the size of the stream imply that the ice was a large mass on high ground—doubtless the Lake District ice-cap.

The material of the half-cone, as exposed along Wisenholme Beck, is largely slate-gravel, tumultuous, earthy or bedded, but includes also loam and clay. The presence in the lower parts of the fan, here and elsewhere, of great blocks of Carboniferous limestone from the outcrop to the west shows that at some period before the separation of the Lake District ice-cap from the Irish Sea ice-sheet the latter had invaded the front of the fells to heights of over 800 ft.

No other fans are yet known to have been thrown down during the Lamplugh pause of the ice-front, but the lake-deltas that will be described later give the approximate position of the ice-front either at the end of the pause or somewhat later.

GLACIAL LAKE ENNERDALE

During the Mockerkin Tarn–Kirkland Pause.—Glacifluvial waters draining away from the front and sides of subaerial fans which they are building up may cut gullies and channels, radiating from the fans, in the surrounding land-surface. On the disappearance of the ice these hollows as a rule are left dry. Dry hollows, Thistle Gill and an unnamed network of channels south of Kirkland, drain south from the Kirkland outwash-fan, one from each end, down the side of Lower Ennerdale. The network leads to a large group of deltas of slate-gravel halfway down the valley-side, extending to Low Stowbank. The tops of the deltas are just below the 600-ft. contour, and their fronts are steep banks that contrast strongly with the gentle slopes below.

The channels south of Kirkland are remarkable on account of their depth and looping. The larger of them are steep-sided, flat-bottomed gullies cut in Skiddaw Slate, to a depth of 50 ft. for much of their course. The trickles of water in them probably never cover the bottoms and certainly are not capable of much erosion. The shallower channels are dry, and several of these are loops, or alternative courses, of the larger ones, cut through higher ground.

Both Thistle Gill and the Kirkland channels arise immediately south of the Kirkland fan—they do not breach the water-shed between the Ehen and Marron valleys, on which the fan rests. Neither, therefore, appears to be an overflow-channel into Lower Ennerdale from a glacier-lake in the Marron valley, even should such have existed at the time at the necessary height, of which there is no evidence. They have been cut by waters draining from the fan or, in the case of the network of channels below its eastern end, possibly from the Lake District ice-front there directly.

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The number and the looping of these eastern channels seem to require for explanation streams that have been limited in position by the presence alongside them of an ice-front varying somewhat in its stand. For only the easternmost channel follows a free path along the bottom of the gentle hollow of the valley-side in which the channels lie. The rest have been cut at different distances up the western slope of the hollow. The depth of each is apparently a measure of the time that the ice-front has lain alongside, before retreating or advancing and thus allowing or forcing the stream to take a lower or a higher path. Possibly, however, the ice-front was stationary, and the stream at different times found different paths along, or just within, its margin. In either case the trend of the channels points to a N. and S. trend of the ice-front.

The deltas at the mouths of the Kirkland channels have been built up in water standing at about 600 ft., and as the wind-gap between Dent and Flat Fell, in the southern wall of Ennerdale, has the characters of an overflow of a glacier-lake and the level of its sill is a little under 600 ft. above O.D., the water is inferred to have been a lake held up by an ice-front to the west across lower Ennerdale and abutting against Dent.

At the end of, or after, the Lamplugh Pause.—Between Lamplugh and Bowness Knott a number of deltas of streams now dead or greatly reduced have been found banked against the hillsides. They differ from the deltas just described in being terraced or compound, each consisting of two, three or four deltas at the following heights :—800 feet; an undetermined height well over 700 ft. (700 + ft., Fig. 5); one somewhat under 700 ft. (700 — ft.); and 600 ft. Each component cuts through that above : the level of the water in which they were deposited was falling by stages. As the height of the lowest stage is the same as that of the hollow between Dent and Flat Fell mentioned above, this water is inferred to have been that of a lake, not that of the sea. Overflows corresponding to some or all of the higher stages may have existed between Flat Fell and Blakeley Raise, as would appear from the contour-lines, but this ground has not yet been examined.

In several cases it is probable that the streams that threw down these deltas had close relations to the ice-cap. The Rakegill Beck deltas lie in, and just outside, the gap between the Lamplugh outwash-fan and Murton Fell, and the 800-ft. member cuts into the side of the fan. The delta is therefore newer than the fan. On the other hand the same member is bounded eastward by a back-slope (shutting in the Cogra Res.) in line with the ice-contact slope of the fan. The back-slope may be merely the remains of the southern part of the latter slope, in which case much of the 800-ft. delta would be merely the southern part of the fan below the notch cut at the 800-ft. level. More probably, however, the presence of the back-slope means that the 800-ft. delta has been banked against an ice-front, that

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is, the ice-front remained in the position it had occupied during the deposition of the fan for a further period, during which the 800-ft. delta at least was formed. In this view, the 800-ft. member is an outwash-delta.

The forms of this and the lower members throw light on the conditions existing in the glacier-lake. The upper surface of the 800-ft. delta is pitted with several kettle-holes; presumably, therefore, blocks of ice were buried in its gravels when it was laid down. All the members except that at 600 ft. are deflected sharply southward on emerging from the hills on to the coastal plain, showing that a strong southerly shorewise current has existed during the early stages of the lake but has disappeared before the close.

Turning now to the more southern terraced deltas we find that all the members are banked against higher ground. But though none of their slopes, therefore, appear to indicate ice-contact, other evidence of the proximity of the ice-cap is clear in one case, that of the lobate delta that hangs on the northern side of Lower Ennerdale above Hunter How. The streams that carried the material of this delta to the lake are dead and could not revive under conditions merely of increased precipitation. Above the delta an E. to W. spur, beginning as Kelton Fell on the east and culminating in Keltonfell Top, runs out from the main mass of the fells and forms the watershed between Ennerdale and Leaps Beck, a tributary of the Marron. The chief feeders of the delta were two parallel streams that flowed right across this spur (one on either side of Pit No. 1 of Keltonfell Mine), the eastern of the pair cutting a steep-sided trench, 30 ft. deep at the crest of the spur, through hard Skiddaw Slate. The western stream, which is known from its delta to have been short-lived and may have completely preceded the other, has cut a shallower trench a few yards away in gravels. Neither trench is deep enough to divert the drainage of Leaps Beck under normal conditions. The shallower begins above the level of the beck and its course is uphill for some distance, until the crest of the spur is reached. The deeper may also rise at first, for it starts at grade at the level of the beck's alluvium, and if it does not rise it is difficult to understand why it has not drained the beck. Unfortunately its thalweg is obscured by trees and a mineral railway.

These trenches show another abnormal feature. On the Ennerdale side of the spur each runs obliquely to the slope of the ground. The deeper cut, in particular, turns nearly west and almost contours the valley-side. And each bends sharply at the commencement of its delta into the course that would be taken by a free current of water descending the maximum gradient, a course which is then maintained.

The streams that have cut these trenches would appear to be possible only if ice were covering or bordering the anomalous parts of their courses. Such an explanation as the diversion

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of Leaps Beck by a snowdrift or ice-barrier across its valley below the intakes of the streams is clearly insufficient. Notably it completely fails to account for the course of the streams along, instead of down, the Ennerdale slope. The streams may conceivably have been marginal to a retreating ice-lobe, but as their channels appear to be similar—in cutting across the pre-glacial topography and in draining both ways—to a hollow described by de Geer,[1] which he ascribes to a swift subglacial stream under considerable hydrostatic pressure, this explanation has been adopted. In Fig. 5 the ice-front is represented as crossing the streams where their trenches turn directly downhill.

The deltas of the streams have been deposited at the following heights :—on the west, possibly at 800 ft., and at 700+ ft.; on the east, at 700+ ft., 700— ft. and 600 ft. The eastern 700+ ft. delta is kettle-holed. No shorewise drift is apparent.

Farther east in Ennerdale two other deltas, each terraced at the four heights, have been built up where Crossdale and Gill Becks emerge on the valley-side. In their cases it is less obvious that the ice-front has had the position shown in Fig. 5, *i.e.*, on the shore of the 800-ft. lake, but in each case certain peculiarities in development of the delta at that level suggest a feeder independent of the present beck. The chief conclusion, however, to be inferred from their presence in Ennerdale is that while an ice-cap sufficient to nourish the streams that deposited the Hunter How delta still lingered on the high ground to the north, Ennerdale west of Gill Beck was clear, along the north side of the valley at least, of Lake District ice.

This conclusion does not run so counter as appears at first sight to the view that towards the end of the Glacial Period the dales have been occupied by valley-glaciers. For the evacuation of Lower Ennerdale may have been precipitated by the standing water at the ice-front floating off bergs, as has been suggested by Shaler to account for the clearance of the Narragansett Basin in New England.[2]

The indentation of the ice-front at Ennerdale during the higher stages of the lake, viewed broadly, may not have been great, for a delta at Rake Beck, north of Bowness Knott, consists of the 600-ft. member only. Possibly this place was still covered by the Lake District ice when the lake stood higher, as suggested in Fig. 5.

The Cause of the Changes in Level.—The group of deltas south of Kirkland indicates a lake-level of 600 ft. only, apparently at the time of the Kirkland pause. The terraced deltas were formed in a lake whose level fell from 800 ft. to 600 ft. and whose period followed the Lamplugh pause. Were the Kirkland deltas deposited after or before the terraced deltas? The first supposition postulates a re-advance of the ice-front

[1] *Geol. Foren. Forh., Stockholm*, bd. 31, 1909, p. 534.

[2] 'The Geology of the Narragansett Basin,' *Mon. U.S. Geol. Surv.*, 3, 1889, p. 68.

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from the stand at Lamplugh to that at Kirkland, but it needs no change of lake-level between the closing stage of the terraced deltas and the period of the Kirkland deltas. The second supposition postulates retirement of the ice-front from the Kirkland to the Lamplugh stand, but involves a raising of the lake-level toward the end of the latter pause from 600 to 800 ft. and a subsequent fall to 600 ft. again.

The first supposition therefore is the simpler, and a re-advance of the ice-cap is likely enough, but the evidence available negatives strongly the corollary that the Lamplugh fan, the terraced deltas and the channels of glacifluvial streams, all in the path of the re-advance, have been invaded and covered by ice. The deposits have undisturbed contours and the channels are free of drift. On the other hand after the evacuation of Lower Ennerdale by the Lake District ice the Irish Sea ice appears to have readvanced to such an extent that it may well have closed the outlet of the glacier-lake at 600 ft. between Dent and Flat Fell, and thus have raised the lake-level to 800 ft., with an outlet over the ice or between Flat Fell and Blakeley Raise.

The evidence of this re-advance is as follows. Lower Ennerdale is mantled with western Drift full of Whitehaven Sandstone and other Carboniferous rocks. The orientation of the drumlin features suggests that the transporting ice has moved straight up the valley, and the western Drift comes to an end at the present lake as a moundy belt (TM, Fig. 5) that crosses the valley from side to side and appears, from its form and its boulder-strewn, part gravelly or sandy, character to be a terminal moraine.[1] As the Drift reaches a height of nearly 700 ft. at Howside the ice that carried it may easily have been higher than 800 ft. at Flat Fell, 3 miles to the south-west.[2]

Ennerdale Water, then, is presumably dammed up, not by the terminal moraine of a Lake District valley-glacier, but by this western Drift, and is a direct descendant of the glacier-lake formerly held up by the ice that has carried the Drift into the dale. The shape of the lake-basin (*see* subaqueous contours, Fig. 5) shows that the barrier extends beneath the present lake as far as Anglers Crag, but not beyond, and it is probably not a coincidence that at Gill Beck, N.E. of this place, evidence of the 800-ft. lake-level, so far as known, ceases. As previously suggested, the high-level lake may there have been limited by the front of the still-lingering Lake District ice, which may also have stopped further advance of the invading tongue of debris-laden Irish Sea ice. Between the two ice-fronts at the period of maximum readvance lay the narrow 800-ft. lake.

[1] In Fig. 5 it is shown as far south as the Anglers Inn, and Mr. Maden finds that it continues, bounding the lower end of the lake.

[2] An advance of an ice-lobe into a hollow occupied by a marginal lake has been shown by Mr. E. M. Anderson ('The Geology of Mid-Strathspey and Strathdearn' *Mem. Geol. Surv., Scotland*, 1915, p. 62) to need a certain 'head' of ice, dependent on the depth of the water and the load of debris carried by the ice.

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The readvance of the Irish Sea ice may have been due directly to relief of counter-pressure on the retreat of the Lake District ice, but it is equally possible that it has had an independent cause.

CONCLUSIONS

1. Towards the end of the Glacial Period the Lake District ice-cap shrank away from the Irish Sea ice-sheet along a line, at present unlocalised, which lay along, or west of, the Marron River above Ullock.

2. During its retreat the ice-cap paused along the line Mockerkin Tarn–Kirkland, and later at the foot of the fells at Lamplugh, at each pause depositing kames but no other form of recessional moraine.

3. The Mockerkin Tarn–Kirkland kame-belt includes outwash-fans and probably outwash- and esker-deltas, the deposits, subaerial and subaqueous respectively, of more or less persistent subglacial streams. The supposed deltas suggest that water was standing in the Marron valley at about 400 ft.

4. The few eskers also present make wide angles with the line of the ice-front and mark the courses of subglacial streams.

5. During the Mockerkin Tarn–Kirkland pause, water was impounded as a glacier-lake by the Irish Sea ice in Ennerdale to a height of 600 ft., its outlet being to the south between Dent and Flat Fell.

6. The Lamplugh kame is an outwash-fan of a great subglacial stream that has debouched at a height of about 1,000 ft. from a wall-like ice-front across the Wisenholme and Rakegill Becks. The country immediately to the west, down to 700 ft. at least, was not under water when the fan was formed.

7. Later, but probably while the ice-front still lay in the same position, the level of glacier-lake Ennerdale was raised to 800 ft., and the lake spread over the foot of the fells to the north as far as Lamplugh. The ice-cap still covered the fells but had disappeared from Lower Ennerdale, possibly owing to flotation of its ice as bergs by the lake-water.

8. The cause of the rise of the lake-level from 600 ft. to 800 ft. was a readvance of the Irish Sea ice, which closed the outlet of the lake at the lower level.

9. This readvance may or may not have been due to relief from the counter-pressure of the Lake District ice-cap.

10. Still later the lake-level fell by stages to 600 ft. again. Presumably renewed retreat of the Irish Sea ice disclosed lower outlets down to that formerly used.

11. The most obvious deposits in the glacier-lake are the deltas of glacier-fed streams.

12. Ennerdale Water is presumably dammed by the Drift, apparently a terminal moraine, deposited by a lobe of Irish Sea ice upon its readvance.

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APPENDIX II

List of Fossil Plants from the Upper Carboniferous Rocks of the Northumberland and Durham Coalfield and their bearing on the Age of the Coalfield.

By R. Kidston, LL.D., D.Sc., F.R.S.

Less is known of the fossil plants and their distribution in the Northumberland and Durham Coalfield than in any of the other important British Coalfields. From many of the Coal Seams not a single fossil plant is recorded and no systematic collecting of these fossils has ever, except at one or two localities, been undertaken. Sufficient plant evidence has however been obtained to enable one to determine definitely the age of the greater portion of the coal-bearing strata, and the only region where any doubt as to this exists is restricted to the rocks associated with the *Brockwell Seam* and the Upper Carboniferous strata lying below it.

Some fossil plants from the highest visible beds in the Coalfield at Claxheugh on the Wear, about 2 miles west of Sunderland, which were submitted to me for examination by Dr. C. T. Trechmann (*Trechmann and Woolacott. On the Highest Coal-Measures or Zone of Anthracomya Phillipsi in the Durham Coalfield. Geol. Mag., Dec. vi., vol. vi., p.* 203, 1919.) contained the following species :—

Neuropteris gigantea Sternb.
Calamites Suckowi Brongt.
Lepidodendron simile Kidston.
Lepidophyllum triangulare Zeiller.
Sigillaria discophora König sp.

These are all species common in the Westphalian Series and although most occur in the basal group (Blackband Group) of the Staffordian Series the plant evidence justifies the beds from which they were derived being included in the Westphalian Series. From these beds then, down to and including the *Three-quarter Seam* which lies a little above the *Brockwell Seam*, the whole Series is of Westphalian age.

From the Brockwell Seam I have only seen the following few plants :—

Neuropteris rectinervis Kidston.
Calamites Schützeiformis K. and J. *forma Waldenburgensis* Kidston pro. sp.
Palaeostachya Ettingshauseni Kidston.
Lepidodendron aculeatum Sternb.
,, *simile* Kidston.
Stigmaria ficoides Sternb. sp.
Trigonocarpus amygdalæformis Göpp. and Berger.

These all occur both in the Lanarkian and Westphalian Series. The absence however of any species characteristic of

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Westphalian rocks and the fact that fossil plants are so scarce on the Brockwell horizon point to a Lanarkian age for the beds. For these reasons, it appears most probable that the Brockwell Seam and the underlying Upper Carboniferous Rocks are of Lanarkian age and as such they are here provisionally classed.

I wish to express my indebtedness for help to the following friends who have most kindly allowed me to examine their collections and to whom my knowledge of the fossil plants of the Northumberland and Durham Coalfield is almost entirely due. To Mr. J. Sim, Cramlington, Mr. J. T. Stobbs, F.G.S., Dr. C. T. Trechmann, F.G.S., Mr. P. Charlton, Ebchester, and especially to Mr. W. Eltringham, Ryton, who has added many new records to the Fossil Flora of the Coalfield. To Prof. Hickling I am indebted for allowing me to examine the Hutton Specimens under his charge in the Armstrong College. I also take this opportunity of acknowledging much kind help received from Mr. E. Leonard Gill, M.Sc., Curator of the Hancock Museum, Newcastle-on-Tyne, during my visits to the Museum.

After the localities in the following list, the name of the Collector to whom I am indebted for the record or the Museum in which the specimen is contained, is indicated by the letters mentioned below.

E. = W. Eltringham; J. S. = J. Sim; T. = C. T. Trechmann; S. = J. T. Stobbs; C. = P. Charlton; H. = Hancock Museum, Newcastle-on-Tyne; H. A. = Hutton Collection, Armstrong College, Newcastle-on-Tyne. B.M. = British Museum.

List of Species.

Westphalian Series.

Fern and Fern-like Plants.

Sphenopteris

obtusiloba Brongt.

Northumberland. *Horizon* :—Bensham Seam. *Locality* :—Backworth Colliery, 6½ miles N.E. of Newcastle. (E.)

Durham. *Horizon* :—Bensham Seam. *Localities* :—Bensham Colliery, Bensham; Jarrow Colliery, Jarrow. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Six-quarter Seam. *Locality* :—Elizabeth Pit, Tanfield Lea. (E.) *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

dilatata L. and H.

Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy's Drift, Hedley Fell, 1 mile N. of Chopwell. (E.)

Sauveuri Crépin.

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

nummularia Gutbier.

Durham. *Horizon* :—Townley Seam *Locality* :—Spen Colliery, 3 miles S. of Ryton. (E.)

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Schillingsi Andrae.
Northumberland. *Horizon :—* ? . *Locality :*—Gosforth, near Newcastle (T.).

Laurenti Andrae.
Durham. *Horizon :* — Six-quarter Seam. *Locality :* — Stargate Colliery, Ryton. (E.)

rotundifolia Andrae.
Durham. *Horizon :*—Five-quarter Seam. *Locality :*—West Thornley Colliery, Tow Law. (S.)

spiniformis Kidston.
Durham. *Horizon :*—Crow Coal. *Locality :*—Phoenix Brickworks, Crawcrook, Ryton. (E.)

pseudo-furcata Kidston.
(*Sphenopteris furcata* L. and H. (*non* Brongt.) Fossil Flora. pl. clxxxi.)
Durham. *Horizon :* –Bensham Seam. *Locality :*—Jarrow Colliery, Jarrow. (H.)

Footneri Marrat.
Durham. *Horizon :*—Crow Coal. *Locality :*—Phoenix Brickworks, Crawcrook, Ryton. (E.)

bella Stur sp.
Durham. *Horizon :*—Crow Coal. *Locality :*—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon :*—Six-quarter Coal. *Locality :*—Tanfield Lea Colliery, Tanfield. (E.)

Schatzlarensis Stur (*pars.*)
Durham. *Horizon :*—Crow Coal. *Locality :*—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon :*—Five-quarter Seam. *Locality:*—West Thornley Colliery, Tow Law. (S.)

Schwerini Stur sp.
Durham. *Horizon :*—Crow Coal. *Locality :*—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Vernoni Kidston ms.
Durham. *Horizon :*—Crow Coal. *Locality :*—Phoenix Brickworks, Crawcrook, Ryton. (E.)

RHODEA

Eltringhami Kidston ms.
Durham. *Horizon :*—Crow Coal. *Locality :*—Phoenix Brickworks, Crawcrook, Ryton. (E.)

DIPLOTMEMA

furcatum Brongt.
Northumberland. *Horizon :*—Low Main Seam. *Locality :*—Cramlington. (J. S.) *Horizon :*—Three-quarter Seam. *Locality :*—Heddon Colliery, 8 miles N.W. of Newcastle-on-Tyne. (E.)
Durham. *Horizon :*—Bensham Seam. *Locality :*—Jarrow Colliery, Jarrow. (H.) *Horizon :*—Crow Coal. *Locality :*—Phoenix Brickworks, Crawcrook, Ryton. (E.)

intermedium Ett. sp.
Durham. *Horizon :*—Six-quarter Coal. *Locality :*—Home Colliery Townley, Ryton. (E.)

Sturi Gothan sp.
Durham. *Horizon :*—Crow Coal. *Locality :*—Phoenix Brickworks, Crawcrook, Ryton. (E.)

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RENAULTIA

gracilis Brongt. sp.

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Stone Coal. *Locality* :—Stargate Colliery, Ryton. (E.)

URNATOPTERIS

tenella Brongt. sp.

Northumberland. *Horizon* :—High Main Seam. *Locality* :—Gosforth. (H.)

Durham. *Horizon* :—Either Stone Coal or Under five-quarter Seam. *Locality* :—Stargate Colliery, Ryton. (E.) *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Townley Seam. *Locality* :—Spen Colliery, 3 miles S. of Ryton. (E.)

CROSSOTHECA

Hōninghausi Brongt. sp.

Durham. *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Stone Coal. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (E.)

DACTYLOTHECA

plumosa Artis sp.

Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—High Main Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.)

ZEILLERIA

delicatula Sternb. sp.

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Avoldensis Stur sp.

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

EREMOPTERIS

artemisiæfolia Sternb.

Northumberland. *Horizon* :—High Main Seam. *Localities* :—Gosforth. (H.) Fawdon, 3 miles N.W. of Newcastle. *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (S.).

Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Maudlin Seam. *Locality* :—Springwell Colliery, Springwell, 3 miles S.E. of Gateshead. (S.). *Horizon* :—Stone Coal. *Locality* :—Chopwell Colliery, 2½ miles N.E. of Ebchester. (C.)

ADIANTITES

adiantoides L. and H. sp.

Northumberland. *Horizon* :— ? . *Locality* :—Gosforth, near Newcastle. (H. A.)

Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow (H.)

PECOPTERIS

Miltoni Artis sp.

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

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MARIOPTERIS

muricata Schl. sp.
Northumberland. *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (S.) *Horizon* :—Yard Coal. *Locality* :—Shiremoor, 3½ miles N.W. of Tynemouth. (H.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. *Horizon* :— Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Five-quarter Seam. *Locality* :—West Thornley Colliery, Tow Law. (S.) *Horizon* :—High Main Seam. *Locality* :—Felling Colliery, Felling. *Horizon* :—Low Main Coal. *Locality* :—Felling Colliery, Felling. (H.) *Horizon* :—Six-quarter Seam. *Locality* :—Elizabeth Pit, Tanfield Lea. (E.) *Horizon* :—Stone Coal. *Locality* :—Stargate Colliery, Ryton. (E.) *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Under Five-quarter Coal. *Locality* :—Stargate Colliery, Ryton. (E.)

latifolia Brongt. sp.
Durham. *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

Loshi Brongt. sp.
Locality :—'Mines of Newcastle.' Brongniart. (Type of species.)

Beneckei Huth.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

ALETHOPTERIS

lonchitica Schl. sp.
Northumberland. *Horizon* :—Yard Seam. *Locality* :—Shiremoor, 3½ miles N.W. of Tynemouth (H.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Six-quarter Seam. *Locality* :—Elizabeth Pit, Tanfield Lea, Tanfield. (E.) *Horizon* :—Stone Coal. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

decurrens Artis sp.
Northumberland. *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (S.) *Horizon* :—Yard Seam. *Locality* :—Shiremoor, 3½ miles N.W. of Tynemouth. (H.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. *Horizon* :— Crow Coal. *Locality* :— Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—High Main Seam. *Locality* :—Felling Colliery, Felling. (H.) *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H.)

cf. *Serli* Brongt.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

valida Boulay.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

DOLEROPHYLLUM

pseudopeltatum Grand Eury.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (Type of *Cyclopteris obliqua* L. and H. pl. xc. A. and B. (No. 136a), (No. 137a), (H.)). *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (Type of *Cyclopteris dilatata* L. and H. pl. xci B, (No. 123a), (H.)).

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Dolerophyllum sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

NEUROPTERIS

heterophylla Brongt.
Northumberland. *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (S.) *Horizon* :—Yard Seam. *Locality* :—Shiremoor, 3½ miles N.W. of Tynemouth
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H.) *Horizon* :—Six-quarter Coal. *Locality* :—Stargate Colliery, Ryton. (E.)

tenuifolia Schl. sp.
Durham. *Horizon* :—'Not far below the Permian.' *Locality* :—Blackhall Colliery Sinking, Claxheugh. (T.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy's Drift, Hedley Fell, 1 mile N. of Chopwell. (E.)

forma major Kidston ms.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

rectinervis Kidston.
Northumberland. *Horizon* :—Three-quarter Seam. *Locality* :—Horsley Drift, Horsley. (E.)
Durham. *Horizon* :—Under Five-quarter Seam. *Locality* :—Elizabeth Pit, Tanfield Lea, Tanfield. (E.) *Horizon* :—Six-quarter Seam. *Locality* :—Tanfield Lea Colliery, Tanfield. (E.) *Horizon* :—Stone Coal. *Locality* :—Stargate Colliery, Ryton. (E.)

thymifolia Sternberg.
Durham. *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H.) (*N. Soretii* L. and H. pl. l.).

Missouriensis White.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Grangeri Brongt.
Durham. *Horizon* :—Stone Coal. *Locality* :—Stargate Colliery, Ryton. (E.)

obliqua Brongt. sp.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy's Hedley Fell Drift, 1 mile N. of Chopwell. (E.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) (*forma impar*). *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H. A.) *Horizon* :—Stone Coal. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

Rytoniana Kidston ms.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

formosa Kidston ms.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Eltringhami Kidston ms.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

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Jongmansi Kidston ms.
Durham. *Horizon* :—Six-quarter Seam. *Locality* :—Elizabeth Pit, Tanfield Lea, Tanfield. (E.)

Osmundæ Artis sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Scheuchzeri Hoffm.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

gigantea Sternb.
Northumberland. *Horizon* :—Hutton Seam (Low Main). *Locality* :—Mickley Coal Coy.'s Drift, Hedley Fell, 1 mile N. of Chopwell. (E.) *Horizon* :—Yard Coal. *Locality* :—Shiremoor, 3¼ miles N.W. of Tynemouth. (H.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.C.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

APHLEBIA

anomala Brongt. sp
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.)

Lebouri Kidston.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (Rhacophyllum? Lebour. Illustr. Fos. Plants. pls. xlii—xliii, 1877.) (H.)

SPIROPTERIS

Spiropteris sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.)

MEGAPHYTON

frondosum Artis.
Durham. *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling.

approximatum L. and H.
Durham. *Horizon* :—High Main Seam. *Locality* :—Jarrow Colliery, Jarrow.

Gwynne-Vaughani Kidston ms.
Durham. *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H.)

Ossimi Kidston ms.
Durham. *Horizon* :— ? . *Locality* :—Etherley. (H.)

AULACOPTERIS

vulgaris Grand Eury.
Durham. *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

EQUISETALES.

CALAMITES

undulatus Sternb.
Northumberland. *Horizon* :—Bensham Seam. *Locality* :—Shiremoor, 3¼ miles N.W. of Tynemouth. (H.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Wedekindi Weiss.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.)

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semicircularis Weiss.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.A.)

Goepperti Ett.
Durham. *Horizon* :— ? . *Locality* :—Land's Pit, near Etherley.

Sachsei Stur.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H.)

Schützeiformis Kidst. and Jong. *forma typicus* K. and J.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) (*C. approximatus* L. and H. pl. lxxvii.)

Schutzeiformis forma Waldenburgensis Kidst. pro spec.
Northumberland. *Horizon* :—Low Main Coal. *Locality* :—Cramlington. (J. S.)

Suckowi Brongt.
Northumberland. *Horizon* :—Low Main Coal. *Locality* :—Cramlington.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Five-quarter Seam. *Locality* :—West Thornley Colliery, Tow Law. (S.) *Horizon* :—Six-quarter Coal. *Locality* :—Stargate Colliery, Ryton. (E.) *Horizon* :—Stone Coal. *Localities* :—Emma Colliery, 1 mile S.W. of Ryton. Townley Pit, Ryton (E.). *Horizon* :—Under five-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

Cisti Brongt.
Northumberland. *Horizon* :—Bensham Seam. *Locality* :—Shiremoor, 3½ miles N.W. of Tynemouth. (H.) *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (J.S.)
Durham. *Horizon* :—Six-quarter Coal. *Localities* :—Emma Colliery, 1 mile S.W. of Ryton. (E.) Stargate Colliery, Ryton. (E.)

jubatus L. and H.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Low Main Coal. *Locality* :—Felling Colliery, Felling. (H.) *Horizon* :—Under five-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester.

carinatus Sternb.
Northumberland. *Horizon* :—Bensham Seam. *Locality* :—Shiremoor, 3½ miles N.W. of Tynemouth. (H.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Low Main Coal. *Locality* :—Felling Colliery, Felling.

paleaceus Stur.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

ASTEROPHYLLITES

equisetiformis Schl. sp.
Northumberland. *Horizon* :—High Main Seam. *Locality* :—Gosforth. (H.) *Horizon* :—Five-quarter Seam *Locality* :—West Wylam Colliery, 2 miles W. of Ryton. (E.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Under Five-quarter

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Seam. *Localities* :—Townley Pit, Ryton. (E.) West Thornley Colliery, Tow Law. (S.) *Horizon* :—Main Coal. *Locality* :—Pelton Colliery, Pelton, 2 miles N.W. of Chester-le-Street. (E.) *Horizon* :—Six-quarter Seam. *Localities* :—Elizabeth Pit, Tanfield Lea Colliery, Tanfield. (E.) Stargate Colliery, Ryton. (E.) *Horizon* :—Stone Coal. *Localities* :—Townley Pit, Ryton. (E.) Emma Colliery, 1 mile S.W. of Ryton. (E.) Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Under Five-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

longifolius Sternb. sp.

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

grandis Sternb. sp.

Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H. A.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Six-quarter Seam. *Locality* :—Stargate Colliery, Ryton. (E.)

Huttoni Lebour.

Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow.

charaeformis Sternb. sp.

Northumberland. *Horizon* :— ? . *Locality* :—Gosforth, near Newcastle. (H.A.)

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell Colliery, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—" One of four seams above Brockwell Coal." *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (E.)

ANNULARIA

radiata Brongt.

Northumberland. *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (J. S.)

Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Five-quarter Seam. *Locality* :—Stargate Colliery, Ryton. (E.) *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H.) *Horizon* :—Stone Coal. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (E.)

dubia Sternb. sp.

Northumberland. *Horizon* :—High Main Seam. *Locality* :—Hazelrigg, Gosforth. (H.)

Durham. *Horizon* :—Six-quarter Coal. *Locality* :—Stargate Colliery, Ryton. (E.) *Horizon* :—Stone Coal. *Localities* :—Chopwell Colliery, 2½ miles N.E. of Ebchester. (C.) Stargate Colliery, Ryton. (E.) *Horizon* :—Three-quarter Coal. *Locality* :—Chopwell Colliery, 2½ miles N.E. of Ebchester. (C.)

ramosa Weiss.

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

galioides L. and H.

Northumberland. *Horizon* :— ? . *Locality* :—Gosforth, near Newcastle. (T.)

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

microphylla Sauveur.

Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Main Coal. *Locality* :—Pelton Colliery, 2 miles N.W. of Chester-le-Street. (E.)

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CALAMOSTACHYS

paniculata Weiss.
Durham. *Horizon* :—Stone Coal. *Locality* :—Chopwell Colliery, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Under five-quarter Seam. *Locality* :—Elizabeth Pit, Tanfield Lea, Tanfield. (E.)

Northumbriana Kidston. sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. *Horizon* :—Low Main Coal. *Locality* :—Felling Colliery, Felling. (B. M.)

PALAEOSTACHYA

elongata Presl sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

gracillima Weiss.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Ettingshauseni Kidston.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H.) *Horizon* :—Stone Coal. *Locality* :—Stargate Colliery, Ryton. (E.)

MYRIOPHYLLITES

gracilis Artis.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H. A.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Low Main Seam *Locality* :—Felling Colliery, Felling. (H.)

SPHENOPHYLLALES.

SPHENOPHYLLUM

cuneifolium Sternb. sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Six-quarter Seam. *Localities* :—Stargate Colliery, Ryton. (E.) Elizabeth Pit, Tanfield Lea, Tanfield. (E.) *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

forma amplum Kidston.
Durham. *Horizon* :—Stone Coal. *Locality* :—Stargate Colliery, Ryton. (E.)

trichomatosum Stur.
Durham. *Horizon* :—Main Coal. *Locality* :—Pelton Colliery, Pelton, 2 miles N.W. of Chester-le-Street. (E.)

LYCOPODIALES.

LEPIDODENDRON

ophiurus Brongt.
Northumberland. *Horizon* :—Beaumont Seam. *Locality* :—Shiremoor Colliery, Shiremoor, 3¼ miles N.W. of Tynemouth. (E.) *Horizon* :—Bensham Seam. *Locality* :—Shiremoor Colliery, Shiremoor, 3¼ miles N.W. of Tynemouth. (H.) *Horizon* :—Yard Coal. *Locality* :—Shiremoor Colliery. (H.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Brass Thill. *Locality* :—Drift at Tanfield Village, near Stanley. (E.) *Horizon* :—Low Main Coal. *Locality* :—Felling Colliery, Felling. *Horizon* :—Townley Seam. *Locality* :—Spen Colliery, 3 miles S. of Ryton. (E.) *Horizon* :—Under Five-quarter Seam. *Locality* :—Emma (Townley) Colliery, 1 mile S.W. of Ryton. (E.)

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dichotomum Zeiller. (Sternb. ?)
Durham. *Horizon* :—Main Coal. *Locality* :—Pelton Colliery, Pelton, 2 miles N.W. of Chester-le-Street. (E.) *Horizon* :—Townley Seam. *Locality* :—Spen Colliery, 3 miles S. of Ryton. (E.)

aculeatum Sternb.
Northumberland. *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (J. S.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow (H.). *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Five-quarter Coal. *Localities* :—Greenside Colliery, 1 mile S. of Ryton. (E.) West Thornley Colliery, Tow Law. (S.) *Horizon* :—Stone Coal. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (E.) *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Townley Seam. *Locality* :—West Wylam Colliery, 2 miles W. of Ryton. (E.) *Horizon* :—Three-quarter Seam—Yard Coal. *Locality* :—Emma Colliery, 1 mile S.W. of Ryton. (E.)

serpentigerum König.
'Newcastle-on-Tyne Coalfield.' (B. M.)

obovatum Sternb.
Northumberland. *Horizon* :—Bensham Seam. *Locality* :—Walter Colliery, between Byker and Wallsend. (S.) *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (J.S.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. *Horizon* :—Brass Thill. *Locality* :—Drift at Tanfield Village near Stanley. (E.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Main Coal. *Locality* :—Pelton Colliery, Pelton, 2 miles N.W. of Chester-le-Street. (E.) *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H.) *Horizon* :—Six-quarter Coal. *Locality* :—Emma Colliery, 1 mile S.W. of Ryton. (E.) *Horizon* :—Stone Coal. *Locality* :—Stargate Colliery, Ryton. (E.) *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Tilley Seam. *Locality* :—Emma Colliery, 1 mile S.W. of Ryton. (E.) *Horizon* :—Townley Seam. *Locality* :—West Wylam Colliery, 2 miles W. of Ryton. (E.)

Peachi Kidston.
Northumberland *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (J.S.) *Horizon* :—Low Main Seam. *Locality* :—Newsham, Durham. *Horizon* :—Brass Thill Seam. *Locality* :—Tanfield Colliery, Tanfield Lea, Tanfield. (E.)

acutum Presl sp.
Durham. *Horizon* :—Stone Coal. *Locality* :—Chopwell Colliery, 2½ miles N.E. of Ebchester. (C.)

simile Kidston.
Northumberland. *Horizon* :—Bensham Seam. *Locality* :—Shiremoor, 3½ miles N.W. of Tynemouth. (H.) *Horizon* :—Hutton Seam. *Locality* :—Mickley Colliery Drift, Hedley Fell, 1 mile N. of Chopwell. (E.)
Durham. *Horizon* :—Brass Thill. *Locality* :—Drift at Tanfield Village, near Stanley. (E.) *Horizon* :—Hutton Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Six-quarter Coal. *Localities* :—Emma Colliery, 1 mile S.W. of Ryton. (E.) Stargate Colliery, Ryton. (E.) Elizabeth Pit, Tanfield Lea, Tanfield. (E.) Townley Colliery, Ryton. (E.) *Horizon* :—Three-quarter Coal. *Locality* :—Emma Colliery, Ryton. (E.) *Horizon* :—Townley Seam. *Locality* :—Spen Colliery, 3 miles S. of Ryton.

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Wortheni Lesqx.
Northumberland. *Horizon* :—Main Coal. *Locality* :—Dinnington Colliery, 6 miles N. of Newcastle-on-Tyne. (E.)

fusiforme Corda.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Stone Coal. *Locality* :—Townley Pit, Ryton. (E.).

LEPIDOSTROBUS.

lanceolatum L. and H.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Six-quarter Seam. *Localities* :—Emma Colliery, 1 mile S.W. of Ryton. (E.) Elizabeth Pit, Tanfield Lea, Tanfield. (E.) Stargate Colliery, Ryton. (E.)

Jacksoni Arber.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow. (H. A.)

spinosus Kidston.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow. (H.)

variabilis L. and H
Durham. Bensham Seam. *Localities* :—Walker Colliery, 6 miles E. of Newcastle-on-Tyne. (S.) Jarrow Colliery, Jarrow. (H.)

LEPIDOPHYLLUM

majus Brongt.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

acuminatum Lesqx.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow.

triangulare Zeiller.
Durham. *Horizon* :—A very few fms. above Main Seam. *Locality* :—Pelaw Brick Yard, Pelaw, 3 miles, E.S.E. of Gateshead. (E.)

LEPIDOPHLOIOS

laricinus Sternb.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—A few fms. above High Main Seam. *Locality* :—Pelaw Brick Yard, Pelaw, 3 miles E.S.E. of Gateshead. (R.) *Horizon* :—Six-quarter Coal. *Locality* :—Emma Colliery, 1 mile S.W. of Ryton. (E.) *Horizon* :—Stone Coal. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

acerosus. L. and H. sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—A very few fms. above High Main Seam. *Locality* :—Pelaw Brick Yard, Pelaw, 3 miles E.S.E. of Gateshead. (E.) *Horizon* :—High Main Seam. *Locality* :—South Shields. *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

HALONIA

tortuosa L. and H.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Townley Seam. *Locality* :—West Wylam Colliery, 2 miles W. of Ryton. (E.)

KNORRIA.

Selloni L. and H. (*non* Sternb ?)
Durham. *Horizon* :—Low Main Coal. *Locality* :—Felling Colliery, Felling.

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Bothrodendron

punctatum L. and H.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—High Main Seam. *Localities* :—Jarrow Colliery, Jarrow. Jarrow Quarry, Jarrow. (*Geol. Survey*, London, No. 5257.)

minutifolium Boulay.
Northumberland. *Horizon* :—Low Main Seam. *Locality* :—Newsham. (H.)
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. *Horizon* :—Six-quarter Coal. *Locality* :—Emma Colliery, 1 mile S.W. of Ryton. (E.)

Asolanus

camptotoenia Wood.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Sigillaria

discophora König. sp.
Northumberland. *Horizon* :—Low Main Coal. *Locality* :—Cramlington. (J. S.) *Horizon* :—Yard Coal. *Locality* :—Shiremoor, 3¼ miles N.W. of Tynemouth. (H.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. *Horizon* :—High Main Seam. *Locality* :—South Shields.

tessellata Brongt.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy.'s Drift, Hedley Fell, 1 mile N. of Chopwell. (E.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Stone Coal. *Locality* :—Emma Colliery, 1 mile S.W. of Ryton. (E.) *Horizon* :—Townley Seam. *Locality* :—Spen Colliery, 3 miles S. of Ryton. (E.)

cf. nodosa L. and H. sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

mamillaris Brongt.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

scutellata Brongt.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy.'s Drift, Hedley, 1 mile N. of Chopwell. (E.) *Horizon* :—Main Coal. *Locality* :—Seaton Delaval Colliery, 3 miles S.W. of Blyth. (E.)
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

vulgaris Artis sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Boblayi Brongt.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Tilley Seam. *Locality* :—Emma Colliery, 1 mile S.W. of Ryton. (E.)

rugosa Brongt.
Northumberland. *Horizon* :—Main Coal. *Locality* :—Seaton Delaval Colliery, 3 miles S.W. of Blyth. (E.)

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elongata Brongt.
Durham. *Horizon* :—Six-quarter Coal. *Locality* :—Stargate Colliery, Ryton. (E.)

orbicularis Brongt.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

laevigata Brongt.
Northumberland. *Horizon* :—Hutton Coal. *Locality* :—Mickley Coal Coy.'s Drift, Hedley Fell, 1 mile N. of Chopwell.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

reniformis Brongt.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Pringlei Kidston.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy.'s Hedley Fell Drift, 1 mile N. of Chopwell. (E.)

coriacea Kidston.
'Newcastle-on-Tyne Coal Field.' (B.M.)

cf. peltata Sauveur.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

ovata Sauveur.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy.'s Drift, Hedley Fell, 1 mile N. of Chopwell. *Horizon* :—Main Coal. *Locality* :—Seaton Delaval Colliery, 3 miles S.W. of Blyth.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon*:—Townley Seam. *Locality*:—Spen Colliery, 3 miles S. of Ryton. (E.) *Horizon* :—Under five-quarter Seam. *Localities* :—Townley Colliery, Ryton. (E.) Clara Vale Colliery near Ryton. (E.)

ovalis Lesqx.
Northumberland. *Horizon* :—Low Main Seam. *Locality* :—Cramlington. (J. S.)
Durham. *Horizon* :—Townley Seam. *Locality* :—Spen Colliery, 3 miles S. of Ryton. (E.)

Schlotheimiana Brongt.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Townley Seam. *Locality* :—Spen Colliery, 3 miles S. of Ryton. (E.)

euxina Zeiller.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy.'s Drift, Hedley Fell, 1 mile N. of Chopwell. (E.)

Sauveuri Zeiller.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

Davreuxi Brongt.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy.'s Drift, Hedley Fell, 1 mile N. of Chopwell. (E.)

cordiformis Kidston.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy.'s Hedley Drift, 1 mile N. of Chopwell. (E.)
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

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scutiformis Zalessky.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy.'s Drift, Hedley Fell, 1 mile N. of Chopwell. (E.)
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Townley Seam. *Locality* :—Spen Colliery, 3 miles S. of Ryton. (E.)

transversalis Brongt.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

diploderma Corda.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

SIGILLARIOPHYLLUM

bicarinatum L. and H. sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H. A.)

STIGMARIA

ficoides Sternb. sp.
Generally distributed in the Coalfield.

minuta Göpp. *pro var.*
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Six-quarter Seam. *Locality* :—Clara Vale, near Ryton. (E.)

reticulata Göpp. *pro var.*
Durham. *Horizon* :—Six-quarter Seam. *Locality* :—Clara Vale, near Ryton. (E.)

STIGMARIOPSIS

anglica Kidston.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

CORDAITALES.

CORDAITES

principalis Gemar sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

borassifolius Sternb. sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H. A.)

CORDAIANTHUS

Pitcairniae L. and H. sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Five-quarter Coal. *Locality* :—West Thornley Colliery, Tow Law. (S.) *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling.

pseudofluitans Kidston.

Samaropsis fluitans Weiss (*non* Dawson) Foss. Flora jüngst. Steink. u.d. Rothl. p 209, pl. xviii, figs. 24–30, 1869.

Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Stone Coal. *Locality* :—Chopwell Colliery, 2½ miles N.E. of Ebchester. (C.)

Volkmanni Ett. sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

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CORDAICLADUS

taxinus L. and H. sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.)

sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

ARTISIA

approximata Brongt. sp.
Durham. *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling. (H.) *Horizon* :—18 fms. from surface. *Locality* :—No. 3 Pit, Chopwell, 2½ miles N.E. of Ebchester. (C.)

transversa Artis sp.
Durham. *Horizon* :—18 fms. from surface. *Locality* :—No. 3 Pit, Chopwell, 2½ miles N.E. of Ebchester. (C.)

SEEDS.

SAMAROPSIS

acuta L. and H. sp.
Northumberland. *Horizon* :— ? . *Locality* :—Gosforth, near Newcastle-on-Tyne. (H. A.)
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow.

POLYPTEROSPERMUM

ornatum Arber sp.
Durham. *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.)

TRIGONOCARPUS

Parkinsoni Brongt.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.) *Horizon* :—Crow Coal. *Locality* :—Phoenix Brickworks, Crawcrook, Ryton. (E.) *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—18 fms. from surface. *Locality* :—No. 3 Pit, Chopwell, 2½ miles N.E. of Ebchester. (C.)

Noeggerathi Sternb. sp.
Durham. *Horizon* :—18 fms. from surface. *Locality* :—No. 3 Pit, Chopwell, 2½ miles N.E. of Ebchester. (C.)

CARDIOCARPUS

congruens Grand 'Eury sp.
Durham. *Horizon* :—Three-quarter Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

CARPOLITHUS

perpusillus Lesqx.
Durham. *Horizon* :—Stone Coal. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.) *Horizon* :—Three-quarter Seam. *Locality*.—Chopwell, 2½ miles N.E. of Ebchester. (C.)

ellipticus Sternb.
Durham. *Horizon* :—Under Five-quarter Seam. *Locality* :—Clara Vale Colliery, near Ryton. (E.)

sp.
Northumberland. *Horizon* :—Hutton Seam. *Locality* :—Mickley Coal Coy.'s Hedley Drift, 1 mile N. of Chopwell. (E.)

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MEGALOSPERUM

inflatum Lesqx. sp.
Durham. *Horizon* :—Six-quarter Seam. *Locality* :—Tanfield Lea Colliery, Tanfield. (E.)

GENERA OF UNCERTAIN POSITION.

PSYGMOPHYLLUM

flabellatum L. and H. sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow.

DICRANOPHYLLUM.

sp.
Durham. *Horizon* :—Bensham Seam. *Locality* :—Jarrow Colliery, Jarrow. (H.)

ROOTS.

PINNULARIA

columnaris Artis sp.
Northumberland. *Horizon* :—Bensham Seam. *Locality* :—Shiremoor, 3¼ miles N.W. of Tynemouth. (H.)
Durham. *Horizon* :—Low Main Seam. *Locality* :—Felling Colliery, Felling.

capillacea L. and H.
Horizon :—Yard Seam. *Locality* :—Shiremoor, 3¼ miles N.W. of Tynemouth. (H.)

? LANARKIAN SERIES.

Durham. *Horizon* :—Brockwell Seam. *Locality* :—Chopwell, 2½ miles N.E. of Ebchester. (C.)

Neuropteris rectinervis Kidston.

Palaeostachya Ettingshauseni Kidston.

Lepidodendron aculeatum Sternb.

,, *simile* Kidston.

Stigmaria ficoides Sternb.

Trigonocarpus amygdalæformis Göpp. and Berger sp.
Horizon :—Brockwell Seam. *Locality* :—Greenside Colliery, 1 mile S. of Ryton. (E.)

Calamites Schützeiformis forma Waldenburgensis Kidston pro sp.

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APPENDIX III

On a Boring for Coal at Westbury, Wiltshire

By J. Pringle.

Early in the year 1914 boring commenced on a site slightly over 200 feet above Ordnance Datum in the grounds of the New Westbury Iron Company's works,[1] which are situated alongside the railway at Westbury Station; and through the courtesy of the manager, Mr. W. J. Love, sanction was given to the Geological Survey in March 1915 to examine the cores at the borehole. Several visits were made until August of the same year when the boring was stopped, and we are indebted to the Directors of the Company for their permission to publish this account. We have also to thank Mr. Love for his valuable assistance during the examination of the cores, and for placing the information contained in the log of the boring at our disposal.

The details of the strata passed through are set forth on the table below. They are based on a personal examination of the cores, which varied from four inches to one inch in diameter. Excepting certain portions of the Inferior Oolite, there was shown a fairly complete sequence of the local Jurassic rocks. Each formation present appeared to exhibit similar lithological characters to those of the corresponding beds outcropping in Somerset and Wiltshire. The boring revealed the existence of a marked break in the sequence of Liassic deposits, proving the absence of the whole of the Middle Lias and the greater part of the Upper Lias. The discovery of Coal Measures at a depth of 1,326 feet below Ordnance Datum is of importance, and although the precise horizon of the beds within the formation remains undetermined, further borings in the area would be justified. It is of interest to note that the first suggestion of the possibility of Coal Measures occurring under the Trias at Westbury was made by W. H. Bell in 1890.[2]

Section of the Jurassic and Carboniferous rocks in the Westbury borehole.

		Thickness. Ft.	in.	Depth. Ft.	in.
	Brown surface soil	8	0	—	
Corallian, 78¾ ft.	Iron ore, sandy at base	4	10	—	
	Whitish-grey coarsely pisolitic limestone	4	0		
	Grey finely oolitic limestone with patches of dark clay	24	10		
	Dark greasy clay, oolitic grains at base	9	0		
	Brownish-black clay	7	0		
	Light brown shelly clay	6	0		
	Brownish-black clay, somewhat sandy at top	17	9		
	Hard brownish-grey calcareous sandstone	5	4	86	9

[1] New Series 1-inch Ordnance Map, Sheet 281; 6-inch map Wiltshire 44 N.E.; Old Series 1-inch Geological Map 14.

[2] W. H. Bell. 'The Buried Palaeozoic Rocks of Wiltshire.' *Wilts. Arch. and Nat. Hist. Mag.*, vol. xxv, 1891, pp. 80—85.

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		Thickness. Ft.	in.	Depth. Ft.	in.
Oxford Clay, 527½ ft.	Grey shelly clay with numerous brown filaments. *Quenstedtoceras* near base	16	0		
	Pale smooth limy clay with septarian nodules	20	0		
	Grey and brownish-grey clays, shelly in places with numerous nodules in upper half. *Quenstedtoceras* spp. plentiful. Some gaps in core-sequence	351	3		
	Soft dark brown greasy clay with *Cosmoceras gulielmi* J. Sow., *Pseudomonotis sp. nov.* &c.	140	0	614	0
Kellaways Rock, 72½ ft.	Greenish-grey sandy calcareous clay with numerous specimens of *Pseudomonotis sp. nov.*, and *Gryphaea sp.*	72	3	686	3
Cornbrash, 8¾ ft.	Dark grey limy clay	2	3		
	Hard grey sandy limestone with *Macrocephalites sp.*	6	6	695	0
Forest Marble, 91 ft.	Pale whitish earthy limestone with bluish-grey shelly patches, sparsely oolitic	3	0		
	Dark grey shelly clay	1	0		
	Smooth compact greenish clay with plant fragments	11	0		
	Light grey limy clay	12	0		
	Greyish-white sandy limestone with thin bands of bluish-grey limestone	9	6		
	Whitish-grey limy clay	54	0		
	Dark bluish-grey oolitic limestone		6	786	0
Great Oolite (Fullonian facies), 207½ ft.	Upper Fullers Earth, 146 ft. — Smooth black and greyish-white clays with *Ostrea sp.* and *Rhynchonella varians* (Schloth.), var. *smithi* Walker	141	0		
	Upper Fullers Earth, 146 ft. — Whitish-grey limestone with a thin clay parting	4	0		
	Upper Fullers Earth, 146 ft. — Soft dark-grey shelly clay	1	0	932	0
	Fullers Earth Rock, 21½ ft. — Hard whitish-grey limestone with thin grey marly bands	21	6	953	6
	Lower Fullers Earth, 40 ft. — Whitish-grey limy clay with thin bands of limestone near base	40	0	993	6
Inferior Oolite, 128½ ft.	Hard fine grained oolite with a thin layer of *Ostrea* shells at top. At 994 ft. limestone is full of worm-borings, and between 1,000 and 1,010 ft. coarsely oolitic beds contain *Anabacia*; cores incomplete	43	6	1,037	0
	No core between 1,037 ft and 1,061 ft.	24	0		
	Brownish-grey sandy limestone. 3 inches of core seen at 1,061 ft. No core between 1,061¼ ft. and about 1,122 ft. Hard grey limestone with Ammonites, 3 inches seen at 1,122 ft.	61	0	1,122	0
	Upper — Soft dark muddy sandstone with two thin bands of sandy limestone. Ammonites at 1,134 ft.	12	0		

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			Thickness. Ft.	in.	
Lias, 174½ ft.	Lias, 48 ft.	No core between 1,134 ft. and 1,152 ft.	18	0	
		Soft dark sandy clay with two thin calcareous bands	18	0	
		Unconformity.			
	Lower Lias, 126¾ ft.	Bluish-grey micaceous clay	82	0	
		Hard grey earthy limestones with marly bands	3	6	
		Dark brown shelly clay with thin band of limestone	3	0	
		Hard whitish-grey limestone with clay bands	24	6	
		Bluish-grey clay with thin bands of grey limestone	9	9	
		Hard whitish-grey limestone with thin beds of grey marl	3	2	
		Dark shaly clay		10	
Rhaetic, 43 ft. 8 in.		Smooth white and greyish-white limestones with a thin bed of dark clay. (White Lias)	27	3	
		Black shales with a thin band of dark limestone. (*P. contorta* shales).	16	5	1
Keuper, 185 ft. 7 in.		Smooth pale greenish marl	8	3	
		Dark red marl	4	0	
		Pale blotchy greenish marl	3	0	
		Red marls veined in places with thin bands of gypsum. A narrow band of greyish-white breccia occurs at 1,473 feet	169	4	
		Whitish compact limestone with pebbles of red quartzite	1	0	1,
		Unconformity.			
Coal Measures, 125½ ft.		Red stained fine grained micaceous sandstones	36	0	
		Grey micaceous sandstone with plant fragments	8	0	
		Grey sandy shale	37	5	
		Hard grey quartzose sandstone and grey micaceous sandstone. Red stained along joint-planes	12	7	
		Grey shales with ironstone nodules. *Calamites* and *Stigmarian* rootlets	31	6	1,6
		Bottom of boring.			

Notes on the formations passed through in the borehole.

Corallian.—The boring was commenced near the base of well-known seam of iron-ore which forms the uppermost mem of the Corallian rocks in the neighbourhood of Westbury. details of the formation, as exhibited in the cores, do not di materially from the description of the beds passed through in iron-work's well as given by Mr. Greenwell,[1] and thus do not for special mention. The base of the Corallian was taken at

[1] *See* H. B. Woodward. 'The Jurassic Rocks of Britain' (*Geol. Surv.*), vol. v., 1895, p. 111.

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		Thickness. Ft. in.	Depth. Ft. in.
Oxford Clay, 527½ ft.	Grey shelly clay with numerous brown filaments. *Quenstedtoceras* near base	16 0	
	Pale smooth limy clay with septarian nodules	20 0	
	Grey and brownish-grey clays, shelly in places with numerous nodules in upper half. *Quenstedtoceras* spp. plentiful. Some gaps in core-sequence	351 3	
Kellaways Rock, 2½ ft.	Soft dark brown greasy clay with *Cosmoceras gulielmi* J. Sow., *Pseudomonotis sp. nov.* &c.	140 0	614 0
Cornbrash, 4½ ft.	Greenish-grey sandy calcareous clay with numerous specimens of *Pseudomonotis sp. nov.*, and *Gryphaea sp.*	72 3	686 3
	Dark grey limy clay	2 3	686 3
	Hard grey sandy limestone with *Macrocephalites sp.*	6 6	695 0
	Pale whitish earthy limestone with bluish-grey shelly patches, sparsely oolitic	3 0	
	Dark grey shelly clay	1 0	
	Smooth compact greenish clay with plant fragments	11 0	
	Light grey limy clay	12 0	
	Greyish-white sandy limestone with thin bands of bluish-grey limestone	9 6	
	Whitish-grey limy clay	54 0	
	Dark bluish-grey oolitic limestone	6	786 0
Upper Fullers Earth, 146 ft.	Smooth black and greyish-white clays with *Ostrea sp.* and *Rhynchonella varians* (Schloth.), var. *smithi* Walker	141 0	
	Whitish-grey limestone with a thin clay parting	4 0	
	Soft dark-grey shelly clay	1 0	932 0
Fullers Earth Rock, 21½ ft.	Hard whitish-grey limestone with thin grey marly bands	21 6	953 6
Lower Fullers Earth, 40 ft.	Whitish-grey limy clay with thin bands of limestone near base	40 0	993 6
	Hard fine grained oolite with a thin layer of *Ostrea* shells at top. At 994 ft. limestone is full of worm-borings, and between 1,000 and 1,010 ft. coarsely oolitic beds contain *Anabacia*; cores incomplete	43 6	1,037 0
	No core between 1,037 ft and 1,061 ft. Brownish-grey sandy limestone. 3 inches of core seen at 1,061 ft. No core between 1,061¼ ft. and about 1,122 ft. Hard grey limestone with Ammonites. 3 inches seen at 1,122 ft.	24 0	1,037 0
Upper	Soft dark muddy sandstone with two thin bands of sandy limestone with Ammonites at 1,1[illegible]	61 0	1,122 0
		12 0	

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			Thickness. Ft.	in.	Depth. Ft.	in.
Lias, 174½ ft.	Lias, 48 ft.	No core between 1,134 ft. and 1,152 ft.	18	0		
		Soft dark sandy clay with two thin calcareous bands	18	0	1,170	0
		Unconformity.				
	Lower Lias, 126¾ ft.	Bluish-grey micaceous clay	82	0		
		Hard grey earthy limestones with marly bands	3	6		
		Dark brown shelly clay with thin band of limestone	3	0		
		Hard whitish-grey limestone with clay bands	24	6		
		Bluish-grey clay with thin bands of grey limestone	9	9		
		Hard whitish-grey limestone with thin beds of grey marl	3	2		
		Dark shaly clay		10	1,296	9
Rhaetic, 43 ft. 8 in.		Smooth white and greyish-white limestones with a thin bed of dark clay. (White Lias)	27	3		
		Black shales with a thin band of dark limestone. (*P. contorta* shales).	16	5	1,340	5
Keuper, 185 ft. 7 in.		Smooth pale greenish marl	8	3		
		Dark red marl	4	0		
		Pale blotchy greenish marl	3	0		
		Red marls veined in places with thin bands of gypsum. A narrow band of greyish-white breccia occurs at 1,473 feet	169	4		
		Whitish compact limestone with pebbles of red quartzite	1	0	1,526	0
		Unconformity.				
Coal Measures, 125½ ft.		Red stained fine grained micaceous sandstones	36	0		
		Grey micaceous sandstone with plant fragments	8	0		
		Grey sandy shale	37	5		
		Hard grey quartzose sandstone and grey micaceous sandstone. Red stained along joint-planes	12	7		
		Grey shales with ironstone nodules. *Calamites* and *Stigmarian* rootlets	31	6	1,651	6
		Bottom of boring.				

Notes on the formations passed through in the borehole.

Corallian.—The boring was commenced near the base of the well-known seam of iron-ore which forms the uppermost member of the Corallian rocks in the neighbourhood of Westbury. The details of the formation, as exhibited in the cores, do not differ materially from the description of the beds passed through in the iron-work's well as given by Mr. Greenwell,[1] and thus do not call for special mention. The base of the Corallian was taken at the

[1] *See* H. B. Woodward. 'The Jurassic Rocks of Britain' (*Mem. Geol. Surv.*), vol. v., 1895, p. 111.

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depth of 86 feet 9 inches, thus including a bed of brownish-grey calcareous sandstone which appears to correspond to the band of rock overlying the Oxford Clay at the bottom of the ironwork's well. Fossils were somewhat rare in the limestones, but the following shells were found in the clays :—*Modiola bipartita* J. Sow., *Ostrea* (*Alectryonia*) *gregaria* J. Sow., *Pecten* (*Chlamys*) *fibrosus* J. Sow., *P.* (*Camptonectes*) *lens* J. Sow., *Pleuromya recurva* ? Phill., and a clavellate species of *Trigonia*.

Oxford Clay.—By 1915, a considerable portion of the clay-cores had broken down owing to weathering, and consequently it was not possible to collect specimens with accuracy with regard to depths between 90 and 474 feet from the surface. Viewed broadly, this formation falls in this boring into two lithological divisions of unequal thickness. The upper part, which is 387 feet thick, consists principally of pale grey marly clays with some darker bands and occasional layers of septarian nodules. The clays are characterised by the presence of numerous specimens of *Quenstedtoceras*, one of which was found about 16 feet from the top of the subdivision, and it is highly probable that both the Mariae and Renggeri Zones are present in their full development, although the limits of each zone could not be determined. The following fossils were obtained :—*Nuculana sp.*, *Ostrea sp.*, *Pecten* (*Chlamys*) *fibrosus* J. Sow., *Pinna mitis*, Phill., *Pleuromya recurva* ? Phill., *Pteria* (*Oxytoma*) *inaequivalvis* (J. Sow.), *Cerithium sp.*, *Quenstedtoceras* cf. *macrum* (Quenst.), *Quenstedtoceras* cf. *lamberti* (J. Sow.) and *Quenstedtoceras sp.*

The lower division is formed by a brown marly clay, 140 feet thick, containing abundant and well-preserved specimens of *Cosmoceras*, which almost rival in beauty the specimens from the same beds in the now inaccessible sections in the railway-cuttings near Christian Malford. The whole of the clay is referred to the Ornatum Zone, and in its lithological characters, the deposit agrees closely with the beds in the same zone passed through in the Kentish borings, where also the brownish hue of the clays is a highly characteristic feature. The following fossils were collected :—

	Depth in feet.
Serpula vertebralis *J. de C. Sow.*	499, 520
Nucula *cf.* oxfordiana *Roeder*	557
Nuculana phillipsi *Morris*	499, 614
Pinna mitis *Phill.*	594
Pseudomonotis sp. nov.	546–557
Cerithium sp.	,,
Cosmoceras gulielmi (*J. Sow.*)	590, 594, 598–602
,, jason *Rein.*	499
Cf. Siemiradzkia bakeriae (*J. de C. Sow.*)	,,

Kellaways Rock.—The greenish-grey sandy calcareous clay closely resembles the beds referred to the Kellaways Rock in the Swindon boring,[1] where it appears to be slightly thinner.

[1] H. B. Woodward. 'Account of a well sinking made by the Great Western Railway Company at Swindon,' *Quart. Journ. Geol. Soc.*, vol. xlii., 1886, p. 287.

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Fossils occurred frequently throughout, and a list of the forms obtained is as follows:—*Serpula sp.*, *Astarte carinata*? Phill., *Grammatodon montaneyensis* (de Lor.), *Gryphaea sp.*, *Lucina rotundata* Roem., *Modiola bipartita* J. Sow., *Ostrea sp.*, *Pecten* (*Syncyclonema*) *demissus* Phill., *Pseudomonotis sp. nov.*, *Trigonia sp.* (clavellate), *Cerithium sp.*, and at the depth of 666 feet *Proplanulites* cf. *koenigi* (J. Sow.). The *Pseudomonotis sp. nov.* is closely related to, if not identical with, a shell from the Kellaways Rock of the shafts and borings in Kent. As pointed out elsewhere,[1] similar shells have been incorrectly referred to *P. ovalis* (Phill.), which is found in the Corallian Rocks. At Westbury, *Pseudomonotis sp. nov.* occurs abundantly in the Kellaways Rock, and ranges upwards into the lower half of the Ornatum Zone of the Oxford Clay.

Cornbrash and Forest Marble.—It was of interest to note that the highest bed of the Cornbrash is identical in aspect and composition with the bed of clay forming the top of the formation in the majority of the boreholes in Kent. At Westbury, it yielded only a few fossils amongst which is a small strongly ribbed *Astarte* referred provisionally to *A. fimbriata* Lycett. In the underlying limestone the following characteristic shells were obtained:—*Pecten* (*Syncyclonema*) *demissus* Phill., *Pseudomonotis echinatus* (J. Sow.), and a large fragment of *Macrocephalites*. The formation appears to be much thinner in the cores than along the outcrops between Trowbridge and Wincanton, where it is estimated to be about 25 feet thick.[2]

The Forest Marble is mainly represented by smooth pale grey clays. They include, however, a thick bed of greyish-white sandy limestone, and several thin bands of bluish-grey oolitic limestone. Near the top some of the clays are of greenish hue, and strongly resemble the lower members of the formation overlying the Great Oolitic limestones in the railway-cuttings near Bicester. Owing to the small size of core, it was difficult to fix the base of the formation, but it was taken at a level where the clays assume a Fullonian hue, so as to include the lowest band of oolitic limestone which is identical in appearance with the numerous thin limestone-bands characterising a level 54 feet higher. Thus assigned, the thickness of the beds is in agreement with the measurements of the sections in the neighbourhood of Frome where the Forest Marble is stated to be about 90 feet thick.[3]

Largely owing to the narrow diameter of the core, few fossils were obtained; these include plant fragments, *Grammatodon sp.*, and *Ostrea sp.*

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[1] G. W. Lamplugh and F. L. Kitchin. 'On the Mesozoic Rocks in some of the Coal Explorations in Kent' (*Mem. Geol. Surv.*), 1911, p. 136.

[2] H. B. Woodward. 'The Jurassic Rocks of Britain' (*Mem. Geol. Surv.*), vol. iv, 1894, p. 439.

[3] H. B. Woodward. 'The Jurassic Rocks of Britain' (*Mem. Geol. Surv.*), vol. iv, 1894, p. 349.

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Great Oolite.—The three subdivisions of Fullers Earth rocks are present. The Upper Fullers Earth Clay, with the exception of two thin greyish-white limestones. consists of grey, greyish-white and black clays, and it closely agrees in thickness with the corresponding beds at Scale Hill, south-east of Batcombe,[1] and in the Stowell borehole.[2] The Fullers Earth Rock also appears in normal development, though yielding no examples of its characteristic fossils, whilst the clay of the Lower Fullers Earth is nearly of the same thickness as that proved at Hemington.[3]

The clays are shelly in places, but most of the fossils occur in a fragmentary condition, and lend no aid in the recognition of the zonal subdivisions. The shells are as follows :—*Rhynchonella varians* (Schloth.), var. *smithi* Walker, *Terebratula* sp., *Astarte sp.*, *Grammatodon sp.*, Lima (*Plagiostoma*) *cardiiformis* (J. Sow.), *Modiola gibbosa* J. Sow., and *Ostrea sp.*

Inferior Oolite.—As already stated, the details of these deposits are incomplete owing to the failure to secure a core while passing through a large part of the formation. Between the depths of 993 feet and 1,037 feet, however, a sufficient amount of core was obtained to allow the recognition of some of the members of the Inferior Oolite present at Hemington.[4] The fossils found in these beds are shown on the table, p. 147. Below the depth of 1,037 feet the formation continues down to 1,122 feet, where a thin band of dark grey limestone yielding fragments of Ammonites was penetrated. The fossils were submitted to Mr. S. S. Buckman, who suggests that they may belong to the Murchisoniae Zone of the Aalenian. The Westbury boring thus differs from the Hemington boring and the sections in the Bath-Doulting district by the presence of the Inferior Oolite deposits of pre-Garantiana date. Saline water commenced to flow when the depth of 1,102 feet was reached.

Lias.—The soft dark muddy sands yielded some fragments of *Dumortieria* at the depth of 1,134 feet from the surface. These shells were identified by Mr. Buckman, who assigns them to the Dumortieria Zone of the Yeovilian. Below this depth, dark sandy clays, 18 feet thick, contained only a few fragments of Ammonites which could not be identified, and it is not known which zone of the Upper Lias rests unconformably on the Lower Lias.

The evidence of the unconformity, however, is complete. The upper beds of the Lower Lias are represented by a bluish-grey micaceous clay, yielding at the depth of 1,176 feet Ammonites

[1] H. T. De la Beche, Memoirs of the Geological Survey, vol. i, 1846, p. 280.

[2] J. Pringle. 'On a boring in the Fullonian and Inferior Oolite at Stowell.' 'Summary of Progress' for 1908 (*Mem. Geol. Surv.*), 1909, p. 83.

[3] T. C. Cantrill and J. Pringle. 'On a boring for coal at Hemington, Somerset.' 'Summary of Progress' for 1913 (*Mem. Geol. Surv.*), 1914, p. 98.

[4] *Op. cit.*, p. 99.

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of the *subplanicosta* or *densinodus* groups. These fossils have also been examined by Mr. Buckman, who refers the clay in which they were found to the base of the Raricostatum Zone. It is certain therefore that the whole of the Middle Lias and probably the whole of the Whitbian deposits are absent. The core-record of the Lower Lias clays and limestones was complete, and proved a thickness of 126 feet. Fossils were comparatively abundant, but, as a rule, they occurred in a fragmentary condition, and the evidence they yielded is not sufficiently definite to determine whether the sequence of zones is complete to the bottom of the formation. The following fossils were obtained :—*Cidaris edwardsi*? Wright, *Rhynchonella sp.*, *Astarte* cf. *camartonensis* Moore, *Gryphaea incurva* J. Sow. *Pecten* (*Syncyclonema*) *liasianus* Nyst., *Pinna sp.*, *Pteria* (*Oxytoma*) *inaequivalvis* (J. Sow.), *Arnioceras*?, and *Schlotheimia*?, and the Ammonites already mentioned.

Rhaetic.—The White Lias retains the characteristic features of the formation displayed at its outcrop, but the core was too narrow to allow a correlation to be made with the subdivisions established by Richardson.[1] The limestones were fossiliferous in places, and yielded *Myophoria postera* Quenst.

When the *Pteria contorta* shales were entered, a reduction in the size of the hole was made, and from this point downwards a core slightly over one-inch in diameter was obtained. So far as could be judged from the limited material, the shales appeared to be highly fossiliferous, and the following forms were obtained :—*Pteria contorta* (Portl.), *Cardium cloacinum* Quenst., *Cardinia*?, *Modiola minima* Moore, and fish scales.

Keuper.—The Tea-green Marls are present, and contain a 4-feet band of dark red marl. They are sharply marked off from the overlying black shales, and pass gradually below into red marl which is veined in places by thin bands of gypsum. A narrow band of greyish-white breccia was passed through at the depth of 1,473 feet, and at the base of the formation is a thin bed of slightly dolomitised limestone with pebbles of red quartzite.

Coal Measures.—When the Palaeozoic rocks were entered at the depth of 1,526 feet from the surface, it was found that the Keuper Marl rests on strata of Coal Measures age. They are represented by a series of fine grained well-bedded micaceous sandstones and grey shales with ironstone nodules, and were penetrated to the depth of 125 feet. The junction was not shown in the core, but the sudden passage from nearly horizontal Keuper beds to highly dipping strata suggests the striking nature of the unconformity. The relationship between the two groups, however, may not be so sharply contrasted as indicated in the cores, as it is believed that the bore was deflected while passing through the basement-bed of the Trias. The highest beds are stained a

[1] L. Richardson. 'The Rhaetic of West, Mid and East Somerset' *Quart. Journ. Geol. Soc.*, vol. lxvii, 1911, p. 1.

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dark red colour down to the depth of 36 feet below the junction with the Keuper Marl. Some of the shales are slickensided, and they strongly resemble fireclays where penetrated by numerous Stigmarian rootlets. No seams of coal were passed through. The sandstones contain numerous plant-fragments, none of which are recognisable, but the grey shales yielded *Calamites sp.*, Stigmarian rootlets, and *Sphenopteris*? These, however, are not sufficient to determine the position of the rocks within the Coal Measures.

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APPENDIX IV

On the Occurrence of Igneous Intrusions in the Trias at Grinshill and Acton Reynald, Shropshire

By R. W. Pocock, B.Sc.

These igneous intrusions were briefly mentioned in last year's 'Summary of Progress.'[1] The following account gives a more detailed description of the occurrence.

Sir Roderick Murchison recorded the discovery of a dyke at Acton Reynald, seven miles north of Shrewsbury.[2]

The part he examined was about four and a half feet wide, cutting through the horizontal beds of sandstone, on which the house is built, from north-west to south-east. He states that, in its course to the south-east, this dyke in passing under the house expands to a width of eight or nine feet and that a second parallel dyke ranges beneath the western part of the house. These, according to his account, are crossed by a third and larger dyke trending E.N.E. to W.S.W., but their point of intersection had already been built over. He regards the two smaller dykes as branches of this larger one.

On the Old Series 1-inch Geological Survey map, Sheet 73 S.W., published in 1855, three short parallel faults are marked running north-west to south-east under the house. The original field map shows these as green lines, possibly intended to represent the dykes.

In the course of the re-survey of the district in 1920, a narrow dyke was observed crossing a ditch half a mile north-west of Clive Hall and a further exposure was found in the bed of a stream about 300 yards to the north-west. The course of the dyke was then traced, by means of surface fragments, from a point just north of Holbrook Farm, in a south-easterly direction to the hill above Acton Reynald, a distance of about 2 miles.

The course of the dyke thus traced is in a direct line with Murchison's two smaller dykes at Acton Reynald. (Fig. 6).

The general trend of the dyke is remarkably uniform in a direction S. 58° E. In its course to the south-east it traverses successively the Keuper Marl, the Waterstones, the Keuper Basement Beds (here represented by the well-known Grinshill Building-stone), the Upper Mottled Sandstone and the Bunter Pebble Beds.

The dyke, averaging only about 18 inches in width, forms no feature at the surface if we except a small rise in the ground where it crosses a field 400 yards south of Hill Farm.

To the north-west of Holbrook Farm the Keuper Marl outcrop is covered by a thick mantle of boulder-clay and the most northerly point at which evidence of the dyke was obtained is

[1] 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, p. 26.

[2] *Proc. Geol. Soc.*, vol. ii. 1835, p. 193; 'Silurian System,' 1839, p. 295.

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at the corner of a field 200 yards north of Holbrook Farm, where several fragments of the rock were found. Further fragments

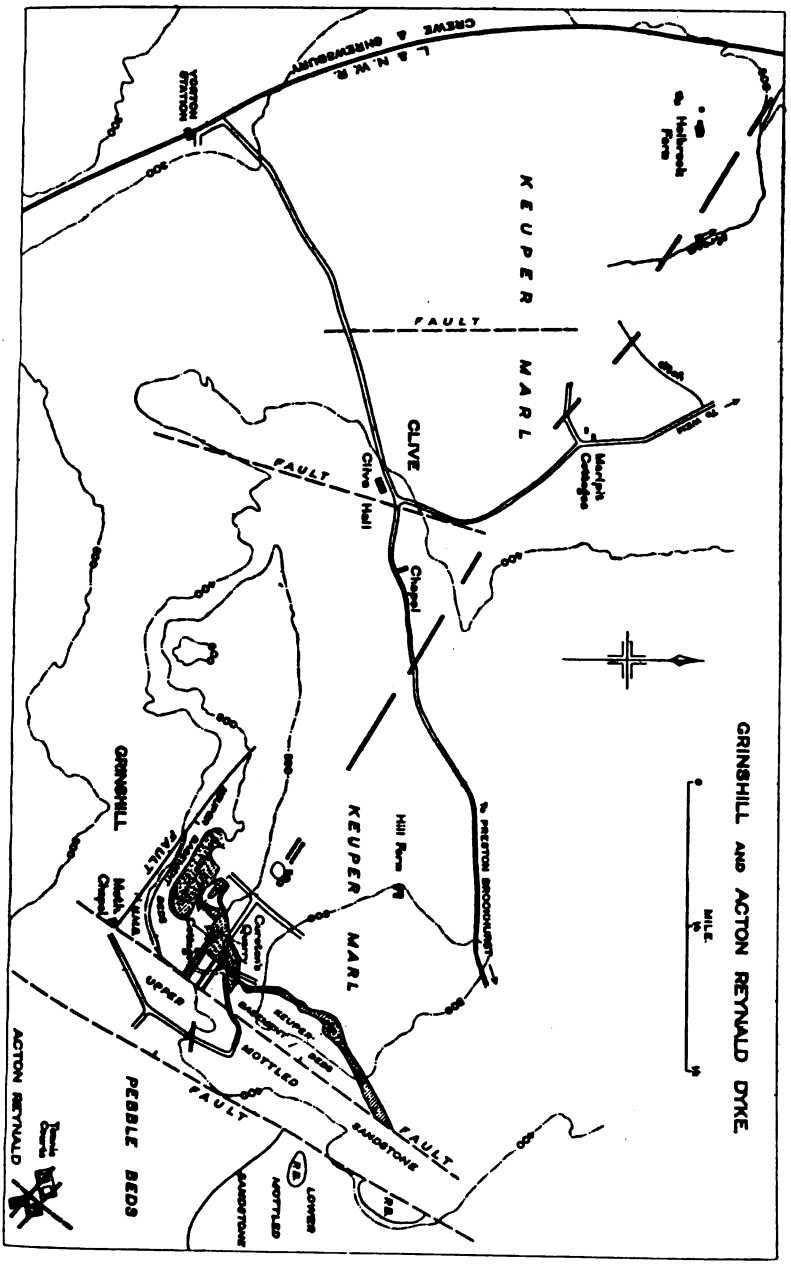

FIG. 6.—*Sketch-map showing the course of the Grinshill and Acton Reynald Dyke.*

were found 200 yards to the south-east of this point. The dyke is exposed about 250 yards further to the south-east in a small

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stream. It is here about two and a half feet wide with a strike S. 60° E. and has altered the Keuper Marl for a few inches on either side. About 10 yards downstream to the north a narrow branch vein is exposed.

The next exposure, about 250 yards east by south of the last, is not quite in the main line of the dyke, possibly due to shifting by a north and south fault for which there is evidence further south. The igneous rock is here seen in a ditch, cutting through Keuper Marl with thin sandstone bands.

About 100 yards down the lane west of Marlpit cottages there is a poor exposure from which fragments of the dyke rock and altered sandstone and marl were obtained.

A second fault seems to cut the dyke just east of the road from Clive to Wem. Beyond this the main direction is again indicated by fragments at a point 400 yards north-east of Clive Hall, and again 250 yards east by north of the Congregational Chapel where many large fragments were found in a hedge running north from the Preston Brockhurst road. Other fragments were met with 250 and 400 yards south-east of the last locality.

The dyke is seen apparently *in situ* 300 yards south by west of Hill Farm and seems to consist of two parallel branches differing somewhat in character. In the adjoining field to the east there is a slight rise in the ground on the line of the dyke which may be due to an expansion of the latter; at this point however there is no exposure.

The line of strike of the dyke crosses the crest of the hill overlooking Acton Reynald Park. Here the Keuper Marl is seen in the well-known Grinshill Quarries resting on about 20 feet of Waterstones or Flag Rock, at the base of which there is a well-defined loose sandy bed known as the " Esk Bed " which averages 9 inches in thickness and forms the upper limit of the Keuper Basement Beds or Grinshill Freestone.

In the Freestone the igneous material appears to have ascended along several more or less vertical and parallel fissures or joints as is indicated by exposures in the hillside. Four distinct branches, each about 2 feet wide, can be seen crossing an old cart track that descends the hill in a southerly direction through the woods from the corner of the old lane 600 yards south by east of Hill Farm.

The most southerly of these branches, when traced towards the north-west, passes through the coal shed of a cottage, along the base of a face of Freestone that forms the north-eastern boundary of the cottage garden and can be seen cutting the face of Freestone that forms the north-western boundary of the garden.

It is seen again in " Cureton's Quarry " 50 yards north-west of the cottage. This section is the best met with. The Freestone in the main quarry has been cut back to the junction with the igneous rock and the latter has been left forming the quarry wall. In one place, however, the quarrying operations

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have been carried further, the dyke rock has been removed, and a deep excavation made behind it. In the north-west face of this excavation the dyke can be seen curving down below the level of the floor of the main quarry, while above a small tongue or apophysis narrows upward into a joint in the sandstone.

In the south-eastern face of the main quarry two separate vertical branches of the dyke can be seen.

There appears to have been no movement of the rocks on either side of the dyke in any of these exposures as the "Esk Bed" is at practically the same level at all points in the quarry.

At the foot of the hill below the quarries an important fault running N. 35° E. appears to have affected the strike of the dyke as is indicated in the next exposure in the old lane 400 yards north-east of the Methodist Chapel, Grinshill. Here the dyke can be seen passing through the bright red sandstone of the Upper Mottled division of the Bunter with a strike N. 80° W. It is about 2 feet wide and has bleached the red sandstone for a distance of 18 inches to 2 feet on either side.

Between this point and Acton Reynald Park there is evidence of another fault running N. 30° E. and throwing down the Upper Mottled Sandstone on the north-west against the Pebble Beds of Acton Reynald Park.

In the Park no exposure of the dyke is now visible, but the rock has been seen in the sides of an old well in the courtyard of the house. This well was filled in in 1893, and new kitchens built over the spot. The dyke was also exposed, in the process of lowering the more westerly of the two tennis courts crossing the court diagonally from north-west to south-east.

From this information the direction of strike appears to be about south-east.

Large blocks of the rock from this locality were dumped near the engine house in the adjoining Apollo's Coppice, and specimens have been obtained from these.

No evidence relating to Murchison's parallel dyke or his larger intersecting dyke could be obtained.

All the evidence tends to show that the dyke is post-Triassic in age as it is intruded into and has altered the Keuper Marl and underlying divisions of the Keuper and Bunter.

The change in strike in the neighbourhood of the faults indicates that its intrusion may be earlier than the main faulting of the district.

Fourteen sections (12071–12084) of the Acton Reynald Dyke in different parts of its course have been prepared for microscopic examination and the following account is contributed by Dr. Flett :—

The rock is a decomposed porphyritic dolerite. Towards its margins the dyke is fine-grained with small porphyritic felspars in a micro-crystalline groundmass. These marginal specimens are sometimes vesicular and are always much decomposed. The central portions of the dyke are dark grey in colour with white porphyritic felspars, up to a quarter of an inch in length, scattered through the groundmass. Under

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the microscope none of the rocks proves to be in good preservation. The pyroxene is entirely replaced by secondary products and it is impossible to be certain whether olivine was originally present. Calcite, chlorite, kaolin and quartz are abundant; it is probable that all the quartz is secondary. The porphyritic felspars in the freshest rocks are labradorite, with complex twinning and a slight development of zonal structure. In some of the more decomposed slides these felspars are albitized. The felspars of the groundmass are also labradorite, where their characters can be determined. Iron-ores—magnetite and ilmenite—are frequent and leucoxene, pyrites and apatite are also common in the slides. The general characters of the rock indicate that it is a porphyritic dolerite which originally was not rich in olivine, and may have belonged to the tholeiite group.

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APPENDIX V

On a Boring at Bootle, near Liverpool

By D. A. Wray, M.Sc.

In 1914, a boring for water was made at Messrs. Bryant and May's Diamond Match Works, Bootle. The actual site is in Linacre Road, 300 yards south of Linacre Road station (Lancashire and Yorkshire Railway), and at a height of about 30 feet above O.D.

Maps.—One-inch New Series Ordnance, 83; Old Series Geological 90 S.E.; Six-inch, Lancashire 99 S.W. Latitude, 53° 27′ 55″. Longitude, 2° 59′ 55″.

The boring was made by Messrs. J. Thom & Co., Engineers, of Patricroft, near Manchester, to whom we are indebted for the record given below. It had been anticipated that under a thin covering of drift the Bunter Sandstones, so dependable as a source of underground water-supply in the country to the immediate south, would have been met with. Instead, however, under a rather abnormal thickness of drift, the Keuper Marls, hitherto unsuspected in this district, were met with and found to attain a thickness of 230 feet. The boring was ultimately carried to a depth of 383½ feet from the surface, and finished in the Lower Keuper Sandstone.

The borehole has a diameter of 7 inches, and is lined for 170 feet; its present yield is about 8,000 gallons of water per hour.

	Thickness. Ft.	in.	Depth. Ft.	in.
Glacial Drift, 77 ft. 8 ins. :—				
Clay and stones	25	0	25	0
Gravel and boulders	5	0	30	0
Clay	7	0	37	0
Gravel and boulders	6	0	43	0
Clay	3	0	46	0
Gravel and boulders	9	0	55	0
Clay	1	0	56	0
Gravel and large boulders	4	0	60	0
Gravel	4	0	64	0
Line of boulders and sand		8	64	8
Gravel	3	0	67	8
Boulders and gravel	10	0	77	8
Keuper Marl, 234 ft. :—				
Rubbly sandstone	1	6	79	2
Sandstone	1	0	80	2
Soft red marl	9	6	89	8
Sandstone	0	9	90	5
Soft marl	10	0	100	5
Sandstone	0	7	101	0
Soft sandy marl	5	0	106	0
Sandstone band	0	8	106	8
Soft red marl	10	0	116	8
Marl	5	0	121	8

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	Thickness. Ft.	in.	Depth. Ft.	in.
Keuper Marl—continued.				
Marl and sandstone plies	9	0	130	8
Red marl and sandstone plies	10	0	140	8
Red marl	7	0	147	8
Red marl and sandstone plies	8	0	155	8
Red and blue marl	4	0	159	8
Marl and sandstone plies	3	0	162	8
Mixed marl	9	0	171	8
Marl and sandstone plies	7	0	178	8
Red marl	6	0	184	8
Red marl and sandstone plies	6	0	190	8
Mixed marl	10	0	200	8
Red marl and sandstone plies	6	0	206	8
Mixed marl	3	0	209	8
Soft mixed marl	2	0	211	8
Red marl and sandstone plies	7	0	218	8
Red marl	5	0	223	8
Red marl and sandstone plies	10	0	233	8
Mixed marl	9	0	242	8
Red sandy marl	20	0	262	8
Mixed marl	8	0	270	8
Red marl and sandstone plies	20	0	290	8
Mixed marl	6	0	296	8
Red marl and sandstone plies	15	0	311	8
Keuper Sandstone (*or Waterstones* ?), 71 ft. 10 ins. :—				
Sandstones	20	0	331	8
Mixed marl	3	0	334	8
Hard sandstone	10	0	344	8
Hard mixed marl	1	4	346	0
Hard sandstone	11	0	357	0
Hard red sandy marl	13	0	370	0
Soft sandstone	2	0	372	0
Hard sandstone	11	6	383	6

This record, combined with the additional data given below, which have been published since the last geological survey of this district, suggest that considerable modification is necessary in the boundaries shown on the Old Series Geological Map 90 S.E.

As long ago as 1884, T. M. Reade recorded the presence of Keuper Marl at Moorside, near Great Crosby,[1] about two miles to the north of the site of the present boring. Subsequently Keuper Marl was also met with in a boring for water at Cook's Lane, Great Crosby.[2] Several shallow borings were made in 1906 at the Battery, to the immediate south-west of Hightown station, and these again revealed the presence of Keuper Marl underlying the Boulder Clay and later deposits.[3] Still farther north, at Altcar, 2 miles east of Formby station, the Keuper Marl was found to attain a thickness of 971 feet[4] while trial borings made by the Lancashire and Yorkshire Railway Company, alongside

[1] *Geol. Mag.*, 1884, pp. 445–447.

[2] *Ibid.* 1901. p. 417.

[3] C. B. Travis. 'On some borings near Hightown' *Proc. Liverpool Geol. Assoc.*, 1908, pp. 11–13.

[4] G. H. Morton. 'Recent borings in the Red Marl, near Liverpool.' *Brit. Assoc. Report*, 1896, pp. 780–781.

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the railway at Altcar Rifle Range station, also showed the presence of Keuper Marl underlying the Glacial deposits.[1] From the foregoing records it seems highly probable that the glacial and later deposits of the Formby, Crosby, and Bootle coastal plain are underlain by Keuper Marl, and not Keuper and Bunter sandstone as is indicated on the Old Series map. It is also possible that the Keuper Marl revealed in the Linacre Road boring is separated from the Bunter sandstones seen at Fazakerley and Walton by the northerly continuation of the prominent north and south fault of Liverpool,[2] which separates the Keuper and Bunter formations throughout its course in the city.

[1] T. M. Reade. 'On some borings at Altcar made by the L. & Y. Rly. Co.,' *Proc. Liverpool Geol. Soc.*, 1900, vol. ix., pp. 359–369.

[2] *See* one-inch Geological Map (Old Series) 79 N.E., of which a new edition is now in progress.

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APPENDIX VI

The Zones of the Kimmeridge and Portland Rocks at Swindon

By C. P. Chatwin and J. Pringle

Attention has been drawn to the succession of beds at Swindon since the Survey acquired part of the collection of fossils formed by the late W. H. Hudleston. These fossils were in the possession of Dr. Catherine A. Raisin, and were presented by her to the Survey in December, 1920.

Various beds, exposed when the collection was made, are now inaccessible, but the fossils obtained from them have assumed importance on account of the development of the zonal classification of the Upper Jurassic rocks. In Hudleston's time the idea of narrow zonal division had not become generally adopted, but he collected carefully, bed by bed, around Swindon, and denoted the order of the strata by attaching to each specimen a label bearing such symbols as "B c," "D a," and "D c." The precise significance of these symbols was for a time a matter of conjecture only; and during the examination of the collection several questions arose which made it clear that a visit to the locality would be profitable. A brief visit was sufficient to enable the various horizons to be identified, but the work was helped considerably by excavations then being made in the cemetery and in the lower part of Messrs. Hill's brickyard. As a result, a zonal sequence has been identified from the base of the Kimmeridge Clay up to the highest beds of the Portland rocks in the district. To a great extent this sequence corresponds to the scheme proposed by Dr. H. Salfeld,[1] but the identification of an horizon temporarily exposed in the digging of graves in the cemetery as his zone of *Perisphinctes eastlecottensis* has led to certain modifications. At the time of Dr. Salfeld's work in the district (1912) there was no exposure of the beds from which the type of this zone-fossil came, although Hudleston had collected extensively from the horizon when it was to be seen in the railway-cutting of the Midland and South-Western Junction Railway to the west of Swindon Town Station.

The specimens on which Dr. Salfeld founded his new species came actually from an horizon much lower than that to which it it was assigned. This horizon is below the Swindon Clay and not above it, as stated (*op. cit.*, p. 430).

The following zonal scheme, established by combining the evidence of certain specimens in the Hudleston collection with that of fossils recorded by various geological writers and with observations made by ourselves, shows that Dr. Salfeld's zonal

[1] *Quart. Journ. Geol. Soc.*, vol. lxix,, 1913, pp. 423–432.

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classification of the Kimmeridge and Portland rocks (here emended) has complete representation in the district.

Zones.		Stratal Sequence.	Thickness. Ft.	in.	Hudleston's Designations.
		[Purbeck beds, resting on]			
Portland Series.	Perisphinctes giganteus & P. bononiensis	Hard white chalky limestone with *Lucina*, *Cerithium*, etc.	3	0	
		Seam of grey marl	0	2	
		White-weathering, compact limestone with small grains of quartz	1	6	
		Dark grey, clayey sand with shelly layers	1	3	
		Sands with Swindon Stone	25	0	B b
	P. pseudogigas & P. okusensis	Sandy limestone	4	6	B c
	P. gorei (Lydite-bed at base).	Sandy limestone (with derived *P. pallasianus* at base)	3	6	
Kimmeridge Series.	P. pallasianus.	Swindon Clay (Blue clay sandy at base)	14–20	0	
		Hard, greenish marl with lydites		8	C b
		Sands and clays with *Exogyra bruntrutana*	3–4		
	P. eastlecottensis (& P. pectinatus *auctt.*)	Green and red marly sandstones.	3–4		D a
		Grey and buff sands with doggers	30–40		D c
	Virgatites spp.	Dark-green sandy clay Dark bluish-grey clay			"Portland Clay."
	Gravesia zones.	Clay in Bazzard's (upper) pit.			
	Aulacostephanus zones	Oil-shales with clays in Bazzard's (middle) pit.			
	Rasenia zones	Clay at Swindon Wharf & Bazzard's (lower) pit.			
	Pictonia	Lower clay in Bazzard's (lower) pit (*fide* Salfeld)			

[*Note.*—The name *Perisphinctes* is not truly applicable to any of the above ammonities. It is used temporarily until the revision-work on these species is published.]

New information concerning the *eastlecottensis* zone proves that the upper part of the Kimmeridgian in this area is in part arenaceous. This is in accordance with the view expressed by

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H. B. Woodward, who stated[1] :—"There can be no question that the clay below the Portland Stone at Swindon is homotaxial with the Hartwell Clay, for although the Swindon Clay is not so fossiliferous as that at Hartwell, yet it has yielded some species, and the beds immediately below the Swindon Clay have yielded many fossils identical with those of the Hartwell Clay, as shown by the lists of Prof. Blake and Mr. Hudleston."

The sequence of Kimmeridge strata at Swindon affords instructive comparison with the succession in Dorset and Kent. In Dorset the clay-facies merges gradually upwards into marly sands—the so-called Portland Sands—which are surmounted by the cherty beds of the Portland Stone. In Kent there is no sandy facies at the top of the Kimmeridgian, but clay conditions continue right up to the base of the Portland Stone series.

The Kimmeridge Clay is at present poorly exposed near Swindon; portions of it can be seen only at two localities, namely, in certain parts of Turner's old clay-pits and in Messrs. Hill's brickyard. The basal clays are not exposed in the district in any natural sections, but the deep well made by the Great Western Railway Company, at the western end of their works, passed through the following :—

		Ft.	in.
	Made ground	8	0
Kimmeridge Clay (42 ft. 1 in.)	Bluish-grey clay, with Ammonites, &c.	42	0
	Pale-grey shelly limestone with *Ostrea deltoidea*		1
Corallian (22 ft.)	Grey and brown earthy limestone with patches of iron-shot grains		6
	Hard, brown, calcareous, muddy clay	2	0
	Bluish-grey shelly clay	19	6
	Limestones, &c.	—	

In the account of the boring from which we have obtained the above particulars of the beds, all of the clays down to the depth of 72 feet were regarded as belonging to the Kimmeridge Clay. It is likely, however, that the actual top of the Corallian was entered at the depth of 50 feet from the surface, since Dr. Salfeld has shown that the clay-facies extends downwards to the zone of *Perisphinctes decipiens*. We believe that the limestone with iron-shot grains should be regarded as the top of the Corallian, since the rock-specimens available show the matrix to be closely similar to the bed of iron-ore at Westbury. Moreover, Mr. E. T. Newton has recorded the occurrence in it of *Ammonites cordatus* var. *excavatus* (= *Amoeboceras serratum*). Our assignment of these beds to the Corallian is in conformity with the view of H. B. Woodward, who remarked that "when we compare the Swindon section with that at Highworth, about 6 miles to the north-east, we might be disposed to put more than we have included with the Corallian rocks at Swindon" (*op. cit.*, p. 119). Unfortunately, few fossils appear to have been preserved from the upper portion of the well.

[1] 'The Jurassic Rocks of Britain' (*Mem. Geol. Surv.*), vol. v., 1895, p. 223.

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Commencing with the lowest beds of the Kimmeridge Series we note that clays with *Pictonia* are recorded by Dr. Salfeld as being exposed in Turner's (Bazzard's) lower pit, now covered up. The presence of the next higher horizon—that of the Rasenia zones—at Swindon is proved by certain specimens collected by Hudleston from the wharf. In the brick and tile yards north of Old Swindon, H. B. Woodward states that he saw about 25 feet of the blue shaly clay, racy near the top, with septaria and selenite. Remains of *Ichthyosaurus*, *Cetiosaurus*, and *Omosaurus* have been obtained from these clays, and it is probable that these are from the same horizon—the Rasenia zones—as the saurian remains from Gillingham in Dorset.

Along the Midland and South-Western Junction Railway, to the south-west of North Lanes, a cutting (since grown over) showed brown and grey clays with septaria, yielding *Exogyra virgula* (Defr.) and *E. nana* (J. Sow.); these probably belong to the same zone. According to Dr. Salfeld, again, the leathery shales at the top of Turner's lower clay-pit contain *Aulacostephanus pseudomutabilis* (de Loriol) and *A. eudoxus* (d'Orbigny), which are characteristic of the higher Aulacostephanus zone. These shales are impure oil-shales, and are similar to the oil-shales found within the same zone at Broad Bench, in Kimmeridge Bay. Dr. Salfeld failed to find evidence of the Gravesia beds, which normally succeed this horizon, but a specimen in the Hudleston collection appears to fill the gap. Some of the higher beds, a short distance below the "Portland Sands," may still be seen in Turner's brickyard, and have yielded, according to Dr. Salfeld, *Virgatites miatschkoviensis* Vischn., *V. sosiae* Vischn., and *V. dorsoplanus* Vischn. These shells characterize the clays between the Yellow Ledge and the oil-shales known as "Kimmeridge Coal" (*Saccocoma* horizon) in Kimmeridge Bay.

In Messrs. Hill's brickyard, highly fossiliferous clays are worked at the present time, and these are shown by the ammonites to belong also to the Virgatites zone. The clays change gradually from a bluish-grey greasy clay through dark-green sandy clay to an uppermost bed of greenish-grey sandy clay, which weathers a tawny colour. In the bluish-grey clay *Protocardia morinica* (de Loriol), *Camptonectes morini* (de Loriol), *Lucina minuscula* Blake, and ammonites with virgatotome type of ribbing occur.

Careful comparison with specimens in the Hudleston collection leaves no doubt that the dark-green sandy clay is the horizon which Hudleston called the "Portland Clay," from which he obtained an extensive collection of lamellibranchs. The species that have been identified are closely similar to the Hartwell lamellibranch fauna, and include the following:—*Camptonectes morini* (de Loriol), *Grammatodon catalaunicus* (de Loriol), *Grammatodon* sp. nov., *Perna bouchardi* Oppel, *Cyprina implicata* de Loriol, *Modiola* cf. *tombecki* (de Loriol), *Protocardia morinica* (de Loriol), *Anatina* sp. nov., *Ostrea* cf. *expansa* J. Sowerby, *O. bononiae* Sauvage, *Modiola bononiensis* (de Loriol), *Astarte hartwellensis* J. de C. Sowerby, and *Syncyclonema nitescens* (Phillips). *Camptonectes*

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morini is particularly abundant, as is also the case at Hartwell; and the occurrence in both clays of the rare *Anatina* sp. nov. is notable. On the other hand, only one adult and two young specimens of *Astarte hartwellensis* were found in the Hudleston collection. *Trigonia pellati* Mun.-Chalmas, and *Astarte saemanni* de Loriol, which occur commonly at Hartwell appear to be absent in this clay at Swindon, but occur above in the sandy beds with *Perisphinctes eastlecottensis*. The prolific lamellibranch fauna characteristic of the Hartwell Clay at Hartwell has its origin therefore in the Virgatites zone.

The clays pass gradually upwards into " sands with doggers," forming what has hitherto been known as the Lower Portland Sand. The junction may still be seen in the southern end of Turner's old brick pit. The sands are poorly fossiliferous except in the uppermost beds, where green marly sandstones with lydite pebbles yield a rich lamellibranch fauna representing many of the Hartwell species. Low down in the series a few fossils have been found in the nodules of fine-grained grey sandstone; two specimens in the Hudleston collection (labelled D c) have been identified as *Syncyclonema nitescens* (Phillips) and *Thracia incerta* (Thurmann).

The fine series of fossils from the upper beds (labelled D a by Hudleston) were collected during the construction of the Swindon and South-Western Junction Railway. These upper beds were at one time (1887) well exposed in the road-cutting below Victoria Street, and the section was recorded by H. B. Woodward (*op. cit.*, p. 214). A similar section was visible in May 1921 in a disused clay-pit south of Stafford Street; this pit has now been filled in, but from time to time the beds are exposed when graves are dug in the old cemetery, in the slope overlooking Clifton Street. Many fine uncrushed ammonites have been found in the material thrown out in grave-digging; these include *Perisphinctes eastlecottensis* Salfeld, *P. rotundus* (J. Sowerby) *P. pectinatus* auctt., and a number of large fragments of ammonites referable to *Pseudovirgatites*. Examination of the type-specimen of *P. eastlecottensis* Salfeld in the British Museum shows that this shell was undoubtedly obtained from this horizon, and that Dr. Salfeld was mistaken in referring it to the lydite-bed above the Swindon Clay. The matrix, which still adheres to part of the specimen, contains examples of the characteristic lamellibranchs of the bed.

Mr. S. S. Buckman, who has examined the type of *Ammonites pectinatus* Phillips in the University Museum at Oxford, informs us that the shells from Swindon that have been thus identified are not related to Phillips's type-form, but probably represent an undescribed species. Similar finely-ribbed shells are found in the oil-shale horizon of Kimmeridge and Corton, and those from this horizon in Lincolnshire have been referred to *A. pectinatus* by Blake. A comparison shows a very close resemblance in external morphology, but unfortunately no traces of sutures

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are to be seen in specimens from the oil-shales. The delicate ribs are crowded, strongly inclined forwards, and bifurcate nearer the umbilicus than the middle of the flank, although inconstancy in this feature may be observed in individual specimens. Occasionally single ribs are interposed, and in adult shells the periphery becomes broad and distinctly flattened. The fragments referred to *Pseudovirgatites* show a close resemblance to the large ammonites which characterise the oil-shale horizon at Corton, where the shales have been mined. The identity of these forms is difficult to establish on account of varying conditions of preservation; consequently, unless phylogeny can be traced, there remains the possibility (which we consider remote) of similar external morphology being repeated by different stocks at more than one horizon. The sands and clays overlying this richly fossiliferous horizon at Swindon are characterized by the abundance of *Exogyra bruntrutana* Thurmann, but no ammonites appear to have been recorded from them.

The overlying Swindon Clay is a blue clay, weathering brown, more sandy in the lower portion and having at its base a hard, green sandy marl with lydite pebbles (C b of Hudleston). Except for the occasional opening of graves in the cemetery, the lower beds of this clay are no longer exposed in the district. The upper limit is seen immediately beneath the floor at the eastern end of the Okus Quarry. Although H. B. Woodward correlated the Swindon Clay with the Hartwell Clay, there was at that time no ammonite-evidence available; during recent visits, however, we were fortunate enough to obtain several specimens, which, together with some collected by Mr. C. H. Gore, show that the Swindon Clay, like the Hartwell Clay, is in the zone of *Perisphinctes pallasianus*. Further evidence of the presence of the zonal ammonites is to be found in the origin of the numerous fragments of *P. pallasianus* included in the lydite-bed which forms the base of the local Portland stone series. These were obviously derived from the Swindon Clay.

With the recognition of this clay as belonging to the *pallasianus* zone, we come to the upper limit of the Kimmeridge series of Swindon. An abrupt change in lithology marks the upper limit of the Swindon Clay and appears to denote that some movement had taken place within the area of deposition. This is borne out by the presence of many lydite pebbles and numerous derived fossils in the succeeding bed, a bluish marly limestone. The extent of the non-sequence may be gauged by the fact that in Kimmeridge Bay nearly 200 feet of clays and sands lie between the upper part of the zone of *P. pallasianus* and the zone of *P. gorei*. The marly limestone, one foot in thickness, is seen in contact with the Swindon Clay only at the eastern end of the Okus Quarry, and its upper edge crops out at the side of the lane in the western end of Pembroke Street.

The Portland rocks which follow this lydite-bed are well exposed in the Okus Quarry and in the old quarries in the Town

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Gardens. The lithological succession is well known from the sections published by H. B. Woodward and other writers, and a palæontological sequence was established by Dr. Salfeld in 1912. He places the band of bluish-grey limestone (3 ft. 6 in.) overlying the lydite-bed in the zone of *Perisphinctes gorei*, and observes that the boundary drawn between the Portland Sands and the Portland Oolite in the Isle of Purbeck would fall above the *gorei* zone at Swindon. The highly fossiliferous sandy limestone known as the "cockly bed" is referred to the zone of *Perisphinctes pseudogigas*, from which he describes a new ammonite as *P. okusensis*. The overlying sands with Swindon Stone are succeeded in the old quarries in the Town Gardens by chalky limestones, and have been referred by Dr. Salfeld to the zones of *Perisphinctes giganteus* and *P. bononiensis*, though up to the present these species have not been recorded from Swindon.

Acknowledgment should here be made of the assistance received from Mr. C. H. Gore, Hon. Curator of the Swindon Museum, who kindly placed the results of his own collection at our disposal.

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APPENDIX VII

The Subdivisions of the Red Rocks formerly classed as Permian in South Staffordshire and the Neighbouring Counties

By Talbot H. Whitehead, M.Sc., A.R.C.Sc.

The red sandstones and marls overlying the Halesowen Sandstones of South Staffordshire were placed by Jukes[1] in the Permian System. Howell[2] adopted the same course with the similar rocks overlying the beds recognised by him as Coal Measures in Warwickshire. These red rocks were later described by Hull,[3] in greater detail and over a wider area, under the term 'Lower Permian, Salopian Type.'

Mr. Charles Ketley[4] in 1875 and Messrs. Meachem and Insley[5] in 1886 expressed the opinion that part at least of the rocks classed by the Geological Survey as Permian belonged to the Coal Measures. This view was confirmed, on palæobotanical grounds, by Dr. Kidston's paper of 1888.[6]

Mr. Cantrill,[7] in 1895, pointed out the close relationship between the Lower Permian of Salopian Type and the Upper Coal Measures. He concluded that the whole of the former should also be regarded as Upper Coal Measures, and described as Coal Measure Passage Beds.

During the re-survey of the North Staffordshire coalfield it was found that rocks forming part of Hull's Salopian Permian were conformable with the Coal Measures, with which they had certain characters in common, and that these rocks contained Coal Measure fossils. They were, accordingly, relegated to the Upper Coal Measures under the name Keele Sandstone Series.[8]

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[1] 'The South Staffordshire Coal-Field' (*Mem. Geol. Surv.*), ed. 2, 1859, chap. iv.

[2] 'The Warwickshire Coal-Field' (*Mem. Geol Surv.*), 1859, chap. iii.

[3] 'Triassic and Permian Rocks of the Midland Counties' (*Mem. Geol. Surv.*), 1869, p. 12.

[4] Ketley, C. 'The Search for Coal under the "Red Rocks" of the South Staffordshire Coal-Field.' *Geol. Mag.*, 1875, p. 197.

[5] Meachem, F. G., and H. Insley. 'Notes on the Rocks between the Thick Coal and the Trias North of Birmingham and the Old South Staffordshire Coalfield.' *Rep. Brit. Assoc.* for 1886 (1887), p. 626.

[6] R. Kidston. 'On the Fossil Flora of the Staffordshire Coal Fields.' Part I. *Trans. Roy. Soc. Edin.*, vol. xxxv, 1888, p. 317.

[7] T. C. Cantrill. 'On the Occurrence of *Spirorbis*-limestone and Thin Coals in the so-called Permian Rocks of Wyre Forest, etc.' *Quart. Journ. Geol. Soc.*, vol. li, 1895, p. 528.

[8] 'Summary of Progress' for 1898 (*Mem. Geol. Surv.*), 1899, pp. 122, 123. It had already been suggested by Mr. John Ward that part of the rocks in question were of Coal Measure age: 'The Geological Features of the North Staffordshire Coal Fields.' *Trans. N. Staff. Inst. Min. Eng.*, vol. x, pt. 5, 1890, p. 14.

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In his paper of 1899 Mr. W. W. King[1] adopted the following classification of the 'Permian' rocks of the region with which he dealt :—

(3). An upper group of marls, with included breccias.
(2). A middle group of calcareous sandstones, locally conglomeratic, interbedded with marls and sandstones.
(1). A lower group of marls and sandstones.

This classification differs from that of Hull only in relegating the breccias to the upper instead of the middle group. This modification appears justified by Mr. King's discovery that bands of breccia occur, interstratified with marls and sandstones, above the 'trappoid breccia' that forms the base of his upper group[2]; and that the breccias pass laterally as well as vertically into marls.[3]

In 1901 Dr. Gibson[4] showed that the sequence of the Upper Coal Measures adopted in North Staffordshire could be recognised in other localities, including South Staffordshire, where "the olive-coloured sandstones and shales . . . of Illey Brook, which lie at the top of the Halesowen Series . . . are succeeded by red sandstones and marls identical with the Keele Series." The red sandstones and marls referred to belong to the lowest division of Hull's Lower (Salopian) Permian.

During the re-survey of the Warwickshire coalfield it was found that the beds identified with the Halesowen Sandstones of South Staffordshire passed conformably upwards into red marls and sandstones corresponding approximately with the Keele Beds of North Staffordshire.[5]

Mr. Cunnington, as the result of further examination of these red sandstones and marls in the central portion of the Warwickshire Coalfield, found that the following sequence could be made out :—

(3). Upper Group.—Red marls and soft red sandstones.
(2). Middle Group.—Hard red sandstones with calcareous conglomerates.
(1). Lower (Keele) Group.—Red marls and sandstones with three Spirorbis limestones.

Of this sequence only the lowest division could be definitely correlated with the Keele Group of North Staffordshire.[6] A similar division into three groups was found applicable at the southern end of the coalfield.[7]

In the Survey memoir on the Coventry Sheet (169) the beds comprised in groups (2) and (3) of the above sequence have been

[1] W. W. King. 'The Permian Conglomerates of the Lower Severn Basin.' *Quart. Journ. Geol. Soc.*, vol. lv, 1899, p. 100.
[2] W. W. King, *op. cit.*, p. 102.
[3] Personal communication from Mr. King.
[4] W. Gibson. 'On the Character of the Upper Coal-Measures of North Staffordshire, Denbighshire, South Staffordshire, and Nottinghamshire' *Quart. Journ. Geol. Soc.*, vol. lvii, 1901, p. 262.
[5] 'Summary of Progress' for 1911 (*Mem. Geol. Surv.*), 1912, p. 25.
[6] *Ibid.* for 1913, 1914, p. 22.
[7] *Ibid.* for 1914, 1915, p. 19.

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described under the local name Corley Beds, which name also appears on the corresponding one-inch and six-inch maps.

Beds including calcareous conglomerates similar to those of the Warwickshire Coalfield were mapped in the area between the Warwickshire and South Staffordshire Coalfields, and along the borders of the northern portion of the latter.[1]

Certain outcrops of these rocks were found to be continuous with those of Hamstead, described by Mr. Hardaker.[2] The name Hamstead Beds, a modification of that author's local term Hamstead Quarry Series, was accordingly adopted and used, in the Lichfield Memoir, to cover "the red beds with conglomerates into which the Keele Group graduates upwards."[3] Mr. Hardaker[4] correlated his Hamstead Quarry Series in part with the Middle Permian and in part with the Upper Permian of Mr. King. If this correlation be accepted it follows that the term Hamstead Beds, as used in the Lichfield Memoir, includes by implication the Middle Permian, and part at least of the Upper Permian, of the latter author's classification.

In any case it seems convenient to use a common term to cover all the rocks belonging to the Middle and Upper divisions of the 'Permian' (of Hull and of King). The use for this purpose, and indeed in anything more than a strictly local sense, of the name Hamstead Beds is undesirable, as that name is already current for certain strata of Oligocene age. It is proposed, therefore, to adopt the name Enville Beds suggested (in the form Enville Series) by Dr. E. A. Newell Arber[5] in 1916.

The Enville Beds may, then, be defined as the equivalent of the Middle Series (B 2) and the Upper Series (B 1) of the Lower Permian of Salopian Type of Hull,[6] and of the Middle Permian and Upper Permian of Mr. King.[7] They comprise a lower Calcareous Conglomerate Group and an upper Breccia Group.[8]

The Calcareous Conglomerate Group consists of calcareous sandstones with lenticular calcareous conglomerates, and subordinate red marls and non-calcareous sandstones.

The Breccia Group consists of red marls with subordinate sandstones, and with breccias in the lower portion. These breccias may be thick and coarse as on the Clent Hills, or compara-

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[1] 'Geology of the Country around Lichfield' (*Mem. Geol. Surv.*), 1919, pp. 59–63, 117–121.

[2] W. H. Hardaker. 'On the Discovery of a Fossil-bearing Horizon in the 'Permian' Rocks of Hamstead Quarries, near Birmingham.' *Quart. Journ. Geol. Soc.*, vol. lxviii, 1912, p. 639.

[3] 'Geology of the Country around Lichfield' (*Mem. Geol. Surv.*), 1919, p. 4. The name 'Hamstead Beds' was, however, first published in the 'Summary of Progress' for 1915 (*Mem. Geol. Surv.*), 1916, p. 8.

[4] *Op. cit.*, p. 654.

[5] 'The Structure of the South Staffordshire Coalfield.' *Trans. Inst. Min. Eng.*, vol. lii, 1916, p. 38.

[6] *Op. cit.*, p. 13.

[7] *Op. cit.*, p. 100.

[8] The names Romsley Group and Clent Group were proposed for these two groups respectively by Dr. Arber, *op. cit.*, pp. 39, 40.

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tively thin and fine as at Gatacre and near Sedgley.[1] They may even be absent, as in the Warwickshire Coalfield, to which district it would perhaps be safer to defer the application of these subdivisions of the Enville Beds.

In the Calcareous Conglomerate Group the calcareous sandstones show over a wide area a tendency to occur in three bands separated by marls and non-calcareous sandstones. The conglomerates come in sporadically in the calcareous sandstones. These conglomerates are characterised by pebbles of limestone (Carboniferous and Silurian) and of red and yellow chert. The matrix is usually highly calcareous. The characteristic pebbles may occur scattered, so as to form a pebbly sandstone, or even isolated in the sandstones at some distance from an actual conglomerate. These calcareous conglomerates and pebbly sandstones are distinct from the 'pellet rocks' and conglomeratic cornstones which occur also in the Keele Beds; though it appears that the calcareous bands of the Enville Beds may in certain localities be represented by beds of the cornstone type.[2]

The calcareous sandstones are themselves lenticular, but are very much more persistent than the conglomerates, and have a marked tendency to recur on what is apparently the same horizon over a wide area. The base of the Enville Beds is placed at the base of the lowest of the calcareous sandstones associated with the calcareous conglomerates, and, as thus defined, appears usually to lie at from 700 to 900 feet above the base of the Keele Beds.

The Keele and Enville Beds together seem to constitute a generally conformable series, though there may occur local non-sequences as, for example, at the base of the 'trappoid breccia.'

It might, perhaps, be considered that the Breccia Group is of sufficient importance to be made a major subdivision of the "Permian" rocks equal in value to the Keele Beds. This would require that the Calcareous Conglomerate Group be made a third co-equal subdivision. This course would, in fact, amount to the adoption of Mr. King's classification (which is a modification of Hull's), the names only being altered. It may be pointed out, on the other hand, that the Breccia Group derives its importance chiefly from the interest excited by the Clent 'trappoid breccia.' This formation may, however, be regarded as a special local development in a series that is predominantly, and over its widest geographical extent, a marl group with subordinate sandstones and breccias.

Considering the 'Permian' rocks of South Staffordshire and the neighbouring counties as a whole, they consist of a series of red sandstones and marls, interrupted, at about the middle,

[1] *See* W. W. King, *op. cit.*, p. 105, and the present 'Summary', p. 32.

[2] *See* W. W. King, *op. cit.*, p. 111, and 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, p. 15.

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by the development of coarse sediments (conglomerates of special type, and breccias). In the absence of any well-defined plane of unconformity, the best major line of subdivision appears therefore to be at the place where these coarse sediments come in. Further, as already pointed out, the detailed correlation of the 'Permian' beds in Warwickshire with those in South Staffordshire is rendered uncertain by the absence of breccias in the former. It appears, however, that a twofold division into Keele and Enville Beds, with the correlations that this implies, can be safely adopted for the Warwickshire beds.

With regard to the geological age of the rocks formerly called Permian in South Staffordshire and the neighbouring counties, we have seen (p. 28) that the view has long been held that part at least of them belongs to the Coal Measures.

The Keele Beds are now, indeed, placed in the Coal Measures by general consent, though their exact correlation is still a subject of dispute.[1]

In the case of the Enville Beds the position is one of even greater uncertainty. Mr. Hardaker[2] obtained from beds belonging to the Calcareous Conglomerate subdivision of the group certain fossils that he considered established the Permian age of the rocks in question. This contention was disputed by Dr. Newell Arber.[3] The matter should, perhaps, be regarded as still *sub judice*; but in the meanwhile, in view of their apparently conformable relations with the beds below, it is convenient to place the Enville Beds provisionally with the Coal Measures.

In conclusion, the classification of the rocks formerly called Permian in South Staffordshire and the neighbouring counties, adopted by the Geological Survey, may be tabulated as follows :—

[Lower (Salopian) Permian of Hull.]	? Upper Coal Measures. Enville Beds (Corley Beds of Warwickshire).	Breccia Group. Calcareous Conglomerate Group.
	Upper Coal Measures. Keele Beds.	

[1] *See* (amongst other papers) R. Kidston 'On the Divisions and Correlation of the Upper Portion of the Coal-Measures, etc.' *Quart. Journ. Geol. Soc.*, vol. lxi, 1905, p. 308.

R. Kidston 'On the Fossil Flora of the Staffordshire Coal Fields.' Part III., *Trans. Roy. Soc. Edin.*, vol. l, 1914, p. 74.

E. A. Newell Arber. 'The Structure of the South Staffordshire Coalfield.' *Trans. Inst. Min. Eng.*, vol. lii, 1916, p. 42.

[2] *Op. cit.*, pp. 655–81.

[3] *Op. cit.*, p. 40.

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APPENDIX VIII

Determination of Iron in Ores and Silicate Rocks.

By F. R. Ennos, B.A. (Cantab.), B.Sc., A.I.C.,
and R. Sutcliffe, M.A. (Oxon), A.I.C.

In a communication published in the *Journal of the American Chemical Society* (1921, XLIII., 1560–1568), G. E. F. Lundell and H. B. Knowles point out some errors, and their causes, in the determination of iron in silicate rock analysis (W. F. Hillebrand, *The Analysis of Silicate and Carbonate Rocks*, Bull. 700 U.S. Geol. Survey, 1919, p. 119). Reduction of the ferric solution by hydrogen sulphide and titration with potassium permanganate, is stated to result in a positive error, which may amount to 0·5 per cent. when the concentration of acid present is low. It is believed by Lundell and Knowles that this is due to the formation, during reduction, of polythionic acids which can be oxidised by permanganate.

The following modification of the usual method is alleged by these authors to minimise the error. The cold solution, of volume 100 ccs., and containing 2·5 per cent. by volume of sulphuric acid, is saturated with hydrogen sulphide for thirty minutes, and then, raised to boiling point during a period of fifteen minutes, with continued passage of the gas. After filtration, the liquid is again saturated with hydrogen sulphide for ten minutes. 15 ccs. of 1 : 1 sulphuric acid are now added, and the liquid boiled down to 50 ccs. in a current of carbon-dioxide, diluted to 200 ccs. with cold water and titrated with permanganate.

Another process, recommended by them for more accurate work, may be summarised thus :—

Saturation of the acid solution by hydrogen sulphide.
Filtration.
Boiling out hydrogen sulphide.
Oxidation by 10 per cent. potassium permanganate solution.
Reduction with sulphur dioxide gas in slightly acid solution.
Boiling out sulphur dioxide in an atmosphere of carbon dioxide.
Increase of acid concentration.
Titration.

H. D. Newton (*Chemical News*, 1908, XCVII, 218) suggests the reduction of iron by titanous sulphate, oxidation of the excess of the latter by bismuth oxide, filtration from the excess of bismuth oxide, and titration with permanganate solution. This method is open to the objection that the platinum in the solution is not recovered and weighed, this being important in accurate work (Hillebrand, *op. cit.*, p. 119, Note 2).

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Previous to the publication of the work of Lundell and Knowles, we had adopted in this department, after careful examination, the use of standardised titanous chloride solution for the iron titration, as this method has been found to be accurate and speedy (E. Knecht and E. Hibbert, "*New Reduction Methods in Volumetric Analysis*"). This reagent has the advantage in general use that it may be employed with an internal indicator (ctr. potassium dichromate) for the determination of iron in either hydrochloric or sulphuric acid solution.

For the analysis of iron ores after extraction with hydrochloric acid (in which method of opening up aluminous minerals are not appreciably dissolved), a satisfactory process to adopt is that recommended by Knecht and Hibbert :—

> The iron in solution having been oxidised to the ferric state by the addition of hydrogen peroxide, and the excess of this reagent destroyed by making the solution slightly alkaline with ammonia and boiling for a few minutes, the ferric hydroxide is dissolved by adding an excess of concentrated hydrochloric acid; 5 ccs. of 20 per cent. ammonium thiocyanate are then added to the liquid after it has been cooled, and the standard titanous chloride run in until the colour is destroyed. If ammonium thiocyanate is used as an internal indicator, it gives the best results when present in large excess, and when the solution is strongly acid.

Organic indicators, including methylene blue ('Microscopic Reagent' and 'Medicinal') have been tried, but we do not recommend their adoption, as the end-points are not sufficiently sharp.[1] For iron titrations ammonium thiocyanate is satisfactory in the presence of hydrochloric acid.

Difficulties occur when dealing with the iron, alumina, titanium and phosphate solution, obtained in the ordinary course of rock analysis.

Firstly, under these circumstances, alumina is often present in large amount, and, when the liquid has been made alkaline and boiled to destroy the excess of hydrogen peroxide after oxidation of the iron, the aluminium hydroxide is rendered somewhat insoluble in acids. This insoluble alumina prevents a notable proportion of iron from being determined by titration.

Secondly, the pyrosulphate fusion of the weighed oxides of the aluminium group involves an unavoidable addition of platinum through corrosion of the crucible; and, as platinum salts have been found to be easily reducible by titanous chloride, and also to give a very strong reddish-brown colour with thiocyanate solutions, an uncertain amount of platinum will cause error in the iron determination.

[1] Some experimental work in hand points to the possibility of obtaining one of these indicators in a more suitable form, the change of colour being even clearer than is the case with ammonium thiocyanate.

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To obviate these difficulties we have devised the following method for the estimation of iron in silicate rocks :—

> The titanium is determined colorimetrically in the solution of the pyrosulphate melt before the usual evaporation to small bulk; the platinum has been found not to interfere with this determination. The solution is then evaporated to about 100 ccs., and the excess of hydrogen peroxide destroyed by adding to the hot liquid nearly enough sulphurous acid to discharge the colour. The solution is saturated with hydrogen sulphide at a temperature of about 90° C.,[1] and then, with a current of the gas passing, heated to boiling point. The sulphur and platinum sulphide precipitate, having been coagulated by boiling for a few minutes, the hydrogen sulphide current is stopped while the liquid is still boiling, and, after hot filtration and washing with very dilute sulphuric acid, the filtrate is cooled and oxidised with dilute permanganate solution until it is faintly pink; 10 ccs. of concentrated hydrochloric acid and the indicator are then added, and the solution titrated with titanous chloride.

This method, besides being more rapid than those suggested by Lundell and Knowles, has been found to give results quite accurate within the limits of experimental error. It has, in addition, these advantages; thionic acids, if formed during the reduction, are completely destroyed by the permanganate; alumina remains in solution throughout the process and so does not entangle any iron; platinum is completely removed in a weighable form; and oxidation by permanganate ensures that the iron is all in the ferric state before the final titration with titanous chloride.

[1] U. Antony and A. Lucchesi, *Gazzetta Chemica Italiana*, Anno XXVI, 1896, I, 211.

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MEMOIRS OF THE GEOLOGICAL SURVEY

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY OF GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

1922

WITH

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AND

REPORT OF THE DIRECTOR

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REPORT

OF THE

GEOLOGICAL SURVEY BOARD

FOR 1922

TO THE LORDS OF THE COMMITTEE OF THE PRIVY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH.

MAY IT PLEASE YOUR LORDSHIPS,

In accordance with our terms of reference, we, the Geological Survey Board, beg to submit our third Annual Report on the work of the Survey and Museum.

1. In our first Report we dealt with the extended scope and opportunities of survey work which had rendered an increase of staff necessary, with the development of the programme of service which was then initiated on the approval of our recommendations and with the appointment of the first instalment of additional officers. In our second Report we noted that authority had been given for the full increase of personnel contemplated. We have now the satisfaction of reporting that successive additions of new members have brought the staff nearly up to the full establishment authorised.

The aim of the work of the Survey is to prepare geological maps of the country, to provide for the continuous collection of systematic records of British Geology, and at the same time to carry out the special investigation of sections of the field which at one time or another acquire fresh scientific or economic importance. The general programme for this work includes (*a*) the continuation of the primary survey of the whole country on a scale of six inches to one mile (" the primary six-inch survey "); (*b*) the systematic revision of early survey work where the need for that is urgent, as it is in not a few areas of great economic importance surveyed from 30 to 50 years ago; (*c*) the collection of reliable records of observations of geological value which emerge in areas that are not at the time under either " primary survey " or " re-survey," the most of these being records which become available in connection with economic exploration or exploitation such as water supply, mining and engineering; and (*d*) the preparation of special reports bringing together for particular subjects information drawn from various areas.

2. In 1922 the staff had not been brought quite up to the full strength, and as the increases were considerable, the programme

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for that particular year was to some extent conditioned by the need of affording to recent recruits suitable opportunities of becoming familiar with those aspects of Survey work which were new to them.

3. Before dealing with the progress made on the expanded programme for systematic " Primary Survey " and " Re-survey " work, we desire to refer to three features in the activities of the year which were all necessary to bring the war-time work of the Survey into due relation with the programme of to-day.

The interruption caused by the outbreak of war gave rise to many loose ends in the primary six-inch survey work then in progress. During the war, the Survey officers were all engaged either on military duties or on special geological service, whether in connection with military requirements or with a view to the utilisation of the mineral resources of Great Britain. The Special Reports of the Survey on these mineral resources have found a wide public, and have proved of much value. Under present economic conditions some of them have little immediate application, but many are of direct and continuing importance, and all are permanent records of material use. These records are being kept, as far as practicable, up to date, and each Report will be revised when a fresh issue is required. Some such reissues and some notable additions either published or prepared in 1922 are mentioned in the Director's Report. This series, put in hand during the war, is likely to be of much use in placing before the public in convenient form sections of the collected records which are always available for reference at the Offices of the Survey.

Again, in several areas field-work was left unfinished or unpublished at the outbreak of war. This has been taken up again and is being completed as rapidly as possible. The preparation of those maps and memoirs which had been unduly protracted has been expedited and is now completed or approaching completion. Full facilities for publication have been restored, so that arrears of issue of Survey records are diminishing rapidly.

Owing to special increase of personnel in the course of the last three years, the staff at present includes an unusually large number of men who, while selected in respect of the high standard of attainment and of aptitude which they had shown as students and workers in geology, had still much to learn in the methods and requirements of work in the Survey. In these matters they have to make good under the guidance and supervision of their District Geologists, and we are pleased to find that the younger members of the staff to-day appear likely to maintain the credit of the Survey. At the same time it ought to be noted that the satisfactory output of work, both in field survey and in publication of results, which marks the records for the year has been attained despite the undoubted handicap imposed by the relatively high proportion of men in the early years of their service.

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4. Seven Field Units have been engaged on surveys in the Districts prescribed by the programme approved for the work of the year, viz.:—

The four field units in areas under survey in the previous years :—

(*a*) London and South Eastern District (primary six-inch survey).

(*b*) Midland District—with North Wales (primary six-inch survey).

(*c*) South West Highland District (primary six-inch survey) summer part of field season; and Ayrshire Coalfield Revision—remainder of season.

(*d*) North Highland District (primary six-inch survey) summer part of field season; and Central Coalfield of Scotland Revision—remainder of season.

The three field units which commenced re-surveys of the following areas in 1921 :—

(*e*) Northumberland and Durham District.

(*f*) Cumberland District.

(*g*) Lancashire District.

The Director's Report gives particulars of the work carried out in each of these areas in the course of the year. The establishment of local headquarter offices in districts which are at a distance from both London and Edinburgh has proved of much advantage both in respect of economical working and in bringing the staff of the Survey into closer relation with those interested and helpful in their work in the areas. It was not found possible to begin the revision of the Fifeshire and Yorkshire Coalfields, but before the close of the year a District Geologist was selected for each of these areas, and after these officers have completed their maps and notes for the areas on which they have been engaged, they will take up the revision work for which they are now detailed.

5. The officers of the Petrographical, Palæontological and Chemical Departments at the headquarters offices have co-operated with the field staff on questions that arose in the course of the work of survey and in the preparation of sections of memoirs in which one or other of these departments was largely concerned. They have also dealt with such current enquiries from other Government Departments, public services, etc., as fell within their special fields.

Attention has been given to opportunities of obtaining information from bore-holes in progress, whether in areas under survey or elsewhere, and the collection of records bearing on mining and on underground water supply is steadily increasing.

6. Important additions have been made during the year to the collections in the Museum of Practical Geology and to the Library. Details of these are given in the Director's Report,

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which also sets out certain new developments in the way of arranging collections at the Museum for exhibition to the public.

7. The Director draws attention in his Report to the inconvenient accommodation for the increased staff at Edinburgh. We are in complete sympathy with the Director's views, and we hope that on the expiration of the lease for the premises in George Square, it may be possible to arrange for more suitable quarters for the staff centred at Edinburgh.

8. In several sections of its enquiries and research investigations the Survey has continued to take advantage of the professional assistance of geologists outside the Survey who have special knowledge and experience of the matters to be discussed. The Director, in his Report, refers to some of the contributions to its publications which the Survey owes to these specialists, and his statement is one which well illustrates the advantage of associating such experts with the Survey from time to time in the interpretation and exposition of particular sections of its results.

Mining engineers and mining companies, public authorities and local geological workers give much voluntary help to the officers of the Survey at work in the field. With but rare exceptions, information as to results of borings and exploratory operations, so far as bearing on mining, water supply and general geological investigations, is made available fully and readily.

9. The programme of field work for 1923 is :—

(*a*) to continue the primary survey on the six-inch scale in the London and South Eastern District, in the Midlands (Wolverhampton district), in the West Highlands (Ardnamurchan and adjacent districts) and in the North Highlands (Sutherlandshire around Altnaharra);

(*b*) to continue revision work on the six-inch scale in the following districts where revised editions of the original six-inch maps are now required :—Lancashire, Cumberland, Northumberland, Yorkshire, Ayrshire, and Central Coalfield of Scotland (Lanarkshire, Stirlingshire and Clackmannanshire);

(*c*) to start the revision of the six-inch maps of Yorkshire and Fifeshire, and to collect all available geological information regarding the Concealed Coalfield of Yorkshire for a new edition of the memoir on that field;

(*d*) to continue the preparation of Reports on British Mineral Resources, including new editions of Reports already published, when occasion arises; to collect and prepare for publication further information regarding underground water supplies, and to obtain records and examine cores of borings for water and for minerals.

F. G. OGILVIE,
Chairman.

May, 1923.

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REPORT

OF THE

DIRECTOR

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1922

During the year 1922 several changes have taken place in the staff of the Geological Survey and Museum. Following upon a competitive selection by the Civil Service Commissioners held in August four additions were made to the list of geologists. Officers appointed to the Survey rank as geologists on probation for two years, after which time, if approved, they receive permanent appointments. In November Mr. C. E. N. Bromehead and Mr. C. H. Dinham were appointed District Geologists and they have been entrusted with the task of preparing for the revision of the survey of the Yorkshire and Fifeshire districts which will be begun in 1923. Till the end of the year both of these officers were to a large extent occupied with completing their maps and notes for the memoirs of the districts in which they had been working during the past field season.

A reorganisation of the Auxiliary Staff of the Survey and Museum was effected in November; three classes are now recognised in these grades, viz.:—Technical Assistants (1st Class), Technical Assistants (2nd Class) and General Assistants, and new conditions of pay have been established for these ranks. No appointments have been made to the Auxiliary Staff during 1922.

In Edinburgh the increase of staff has necessitated the provision of additional accommodation, and the rooms in Sheriff Court Buildings, George IV Bridge, which were for many years the offices of the Geological Survey (Scotland) have been assigned to it again by H.M. Office of Works. The inconvenience of having part of the geological staff working in a separate building is considerable, and the present arrangement can only be regarded

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as temporary. The need of new accommodation in Edinburgh suitable for the staff and the collections of maps, rocks, and fossils, in one building, will have to be recognised when the lease of the office in George Square expires.

Owing to the large number of new appointments to the staff of geologists during the last two years a heavy burden has rested on the district geologists who have the duty of training beginners in field work and maintaining the standard of surveying at its old level. This work, however, is being successfully overtaken and all, except one, of those who have completed the probationary period have been accepted for the service. The district geologists also are, in many cases, of recent appointment, or are in charge of new districts. These circumstances tend to retard the production of finished work. The Geological Survey, in fact, within the last three years, has been expanded and rearranged, and numerous alterations have been made in its methods and its fields of work, although as far as possible the old and well tried lines of progress have been followed. A good start has been made with the survey of the new districts, viz.: Cumberland, Northumberland and Lancashire. In each of these areas the district geologists in charge have assiduously collected mining information, and have got into touch with the industrial interests concerned with geological problems. The revision of the six-inch mapping has proceeded smoothly, and the publication of six-inch and one-inch maps is now to be started. Three one-inch sheets in Cumberland and three in Northumberland are reported as completed and the dry-proofs are being prepared for engraving. A few six-inch coalfield maps in each of these districts are also ready to be dry-proofed, but the mining information which has to be compiled in the northern coalfields is often very heavy owing to the long period which has elapsed since the last edition of the Geological Survey map was published, and progress with the work is necessarily slow. The work of the staff in the new districts, in fact, has been largely taken up in the study of the correlation and sequence in each field, and, until these preliminary investigations are completed, the preparation and publication of maps is often impossible. In Northumberland and Cumberland each unit has been investigating two kinds of ground: one in the worked coalfields, where there is much information to be obtained from bores and plans; and the other in the more purely agricultural districts, where mining has not been so actively prosecuted and which are often more suitable for the training of beginners in field geology. In Lancashire it has been found necessary to make a very careful investigation of the correlation of the various grit beds and coal seams and a special study of the fossil zones before arriving at definite conclusions regarding the sequence of the rocks and the thickness of the recognised subdivisions.

The help accorded to the Survey officers by mining engineers and local geologists has been of the greatest value in all these districts, and has greatly accelerated the progress of the work.

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In 1921 the North Wales coalfields and the Midland districts were consolidated into one district under Mr. T. C. Cantrill. Unfortunately, this officer has been prevented by ill-health from participating in the field work during 1922, and special arrangements have had to be made to carry on the work. Satisfactory progress, however, can be reported, as the Liverpool Map and Memoir (Sheet 96) are passing through the press and three other maps and memoirs, Wem (Sheet 138), Birmingham (Sheet 168) and Flint (Sheet 108) are being prepared for publication. There still remain in this district a number of maps on which work has been begun but not completed, a state of affairs to some extent resulting from the dislocation of work arising from the war and the subsequent changes of personnel, but every effort is being made to secure early completion and publication of the work.

In the London district three one-inch sheets were completed during the year: Hertford (Sheet 239), North London (Sheet 256), and Dartford (Sheet 271), and the maps can now be dry-proofed and the memoirs written. The work left unfinished at the outbreak of war has accordingly been brought to completion. The arrears of old work in this district are now greatly reduced, and publication will be abreast of the state of the field survey as soon as the maps and memoirs now in hand have passed through the press. This unit has published two memoirs during the year, London (special map) and Beaconsfield (Sheet 255); and the Aylesbury Memoir (Sheet 238) is printed off and will be published shortly.

In Scotland the training of young geologists presents special difficulties owing to the variety and complexity of the ground surveyed. Each member of the staff spends part of the year in the coalfields and adjacent districts and part in the Highlands or Western Islands. A knowledge of petrology is often of great advantage in the metamorphic and volcanic areas. Progress in consequence may be slow if the ground is intricate and the time of district geologists and senior geologists is taken up in looking after the beginners. Attention has specially been directed during last season to finishing sheets that have been some time in hand. The Scottish sheets are twice as large as the English sheets and require a longer time to survey. In the Western Islands two sheets have been finished during the year, Tiree (Sheet 42) and Coll (Sheet 51), and the survey of the outlying islands to the west of Mull is now finished. The maps and memoirs are to be put in hand as soon as more urgent work is despatched. On the mainland the survey of Ardnamurchan and the Strontian district (Sheet 52) has now been going on during parts of two field seasons, and, though the geology is very intricate, satisfactory results are being attained.

In the North-East Highlands the Lairg Sheet (102) was finished. The adjacent sheet to the east, Brora (103), was surveyed many years ago and is not up to present day standards. Consequently it has been decided to make some revision of

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that ground in order to complete the information and render it possible to publish a colour-printed map of that district along with the adjoining maps. It is expected that this will be accomplished in the coming field season. For some years Dr. Lee and Mr. Buckman have been studying the fossiliferous Jurassic rocks of the Brora and Helmsdale districts and the results of their work will be available for publication in the new map and memoir. Some progress was made also in the survey of the Altnaharra Sheet (108) which, with Achintoul (109), will be now pushed forward as rapidly as circumstances allow. These are the only remaining sheets of Sutherlandshire to be published as geological maps. A special geological map of the complicated Assynt area, on the scale of one inch to one mile, is in the press.

In the Scottish coalfields the revision of North Ayrshire has been continued and one-inch Sheet 22 (Kilmarnock), which has been a very interesting and difficult piece of work, is nearing completion. Meanwhile the publication of the six-inch coalfield maps of that area is being rapidly advanced and a number of the Sheets are now issued or in the press. A memoir on the valuable Bauxitic Clay deposits of the Saltcoats and Kilwinning district was published during the year, as sufficient confidential information had been released by mining engineers and others interested in that field to make possible the publication of the more important facts and the chemical analyses. It has been decided to issue special economic memoirs on the Ayrshire coalfield similar to those that have been published on the Central Coalfield of Scotland, and the first part of the memoir on the Economic Geology of North Ayrshire is now being written. It describes the Dalry, Beith and Stewarton districts, including about twenty three six-inch quarter sheets. This was formerly an important iron-mining area and it has important deposits of limestone, fireclay and coal. The second part of this memoir will follow containing the description of the Carboniferous rocks of the Kilmarnock and Irvine districts.

The Central Coalfield of Scotland includes the coal mining districts of Renfrewshire, Stirlingshire, Dumbartonshire, Linlithgowshire and most of Lanarkshire. The revision of the maps of this field was well advanced before the war put a stop to publication, and when the war ended much additional information had become available. The new six-inch maps are now practically all published and the few remaining ones will shortly be issued. The principal one-inch map of this district (Sheet 31) is being engraved, but it is very complicated and consequently there has been delay. Field work is now being carried on in the smaller outlying coalfields of Muirkirk, Douglas and Alloa. The sixth part of the Memoir on the Economic Geology of the Central Coalfield of Scotland is nearly completed in manuscript. The special memoir on the Glasgow district is sold out and a revised edition must be taken in hand.

The investigation of British mineral resources which has taken up a large part of the time of the staff since 1914 has been

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continued during 1922, and several new volumes of the Special Reports have made their appearance. One of these is an account of Scottish Cannel Coals and Lignites (Vol. XXIV). Two others deal with Lead and Zinc Ores (Vol. XX—North Cardiganshire and West Montgomeryshire and Vol. XXIII—West Shropshire and North Wales, Pre-Carboniferous). A third edition of the Barytes and Witherite report has been issued. Several other volumes of this series are in the press and will be published soon. Two memoirs describe the Lead and Zinc Ores of the North of England and Derbyshire. These will complete the descriptive accounts of British resources of Lead and Zinc Ores. A new edition of the Fluorspar report (Vol. IV) was published and a third edition of the Tungsten and Manganese report (Vol. I) is in the press. The first part of the report on Copper Ores of England is also printing (Vol. XXVII), and the second part is in preparation. A memoir on the chemistry of British Fireclays, containing many analyses made in the Survey's laboratory, is now in hand. A memoir on the microscopic and mineralogical characters of British iron ores is in contemplation. The first edition of the report on the Hæmatites of Cumberland is nearly sold out and a new edition is being prepared.

When these reports have been published it will appear that the mineral resources of Great Britain have been thoroughly examined, and though the accounts are necessarily brief they are up to date and reliable. Every British active mine working mineral deposits (apart from coal and oil shale) will have been visited by the Survey geologists during the last few years. The fact that several of the reports have passed through two or three editions shows that they have been appreciated and the information has been found useful both by the mining industry and the general public. The outburst of activity due to demand under war conditions led to the opening of many mines, and this afforded a very favourable opportunity for collecting information, much of which would have been lost if the work of preparing the reports had not been undertaken during the period when the mines were active. The state of the mineral market of late has not been such as to encourage mining in Britain, and many mines have recently closed down.

The mining plans of the older mines which have not been worked during or since the war have been examined where accessible. Many particulars have also been collected regarding the history of mining in the various parts of Britain where mineral ores have been produced in former times.

As the reports on mineral resources are sold out new editions will be prepared and a periodical revision of the information will be undertaken. In such cases all the active mines are visited. The assistance of the mining engineers in charge is readily given and any new developments are placed on record. Specimens of the ores have been collected and deposited in the Museum of Practical Geology, where they form a valuable mass of material representing the economic minerals of Great Britain.

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Useful information regarding water supply from underground sources is frequently received, and the collection of records of wells and borings for water is constantly increasing. This information is incorporated into the ordinary sheet memoirs wherever it appears to be of sufficient importance; for example the Liverpool memoir and the Coventry memoir, now in the press, contain chapters on underground water supply.. Most of it, however, is reserved for the special Water Supply memoirs which deal with county areas and not with the individual geological Sheets. One water supply memoir has been published during the year (Cambridgeshire, Huntingdonshire and Rutland) and three others have been completed in manuscript, viz. :— Wiltshire, Dorsetshire and Gloucestershire. This completes the description of practically the whole of the counties of the south and east of England, where the Secondary and Tertiary rocks furnish important supplies of water through wells and borings. Attention is now to be directed to some of the Midland Counties where the rapid growth of industrial populations has occasioned increased demands for pure water, and where it cannot readily be obtained from surface supplies. Leicestershire and Derbyshire will probably be the first of these counties to receive attention. The services of Mr. W. Whitaker, F.R.S., have again been enlisted for this work and his long experience and intimate knowledge of the subject have been most freely placed at the disposal of the Survey in preparing new memoirs of this series. Mr. Richardson has written the memoir on Gloucestershire water-supplies and from personal familiarity with the district has been able to supply particulars of practically every underground water supply in that county.

In these and other cases advantage has been taken of the special qualifications possessed by geologists not on the Survey, but expert in various departments of geological work, and willing to undertake the preparation of memoirs on their special fields of research. Mr. Osborne White, during the year under consideration, has written an account of the geology of the country south and west of Shaftesbury, which is now passing through the press. The old hand-coloured one-inch sheets of this area (Old Series 15 & 18) have been adapted for colour-printing as New Series Sheet 313, and as it proved desirable to revise the information in certain parts of the district Mr. Dines and Mr. Hollingworth, under the superintendence of Mr. Howe, have mapped the gravels and alluvial deposits, and the results of their work will be shown on the new map.

For many years it has been recognised that a systematic description of the fossil plants of the British Carboniferous rocks was very much needed in connection with the identification of the horizons of coal seams and other strata in the British coal-fields. Dr. Robert Kidston, who has devoted many years to palæobotanical research on these problems, and whose name is sufficient guarantee for the accuracy and thoroughness of the work, has volunteered to undertake the preparation of a memoir

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on this subject. It is intended to publish this monograph in parts, which will probably be ten in number, each containing a description of a group of species, with illustrative plates, and full records of the horizons and localities in Britain at which specimens have been obtained. Three parts are now in the press: they have from twenty to thirty plates for each part and it is expected that they will be issued to the public early in 1923. This palæobotanical monograph will form a valuable supplement and companion to the memoirs which the Geological Survey has been publishing on British coalfields and will be all the more useful because palæobotanical details have not generally been included in the geological memoirs, as, without descriptions and figures, it was difficult to show adequately the bearing of the evidence obtained from fossil plants on the geological sequence.

Among other specialists who have assisted the Geological Survey with geological and palæontological information during the year 1922 we may mention Mr. Buckman, who has determined a large number of ammonites and brachiopods from Brora and Helmsdale districts; Dr. Spath, who has determined Cretaceous ammonites; Miss Elles, graptolites; Professor Watson, Carboniferous vertebrates; and Mr. T. H. Withers, cirripedes.

In the Museum of Practical Geology attention has specially been directed to the proper curation and exhibition of the growing collection of British economic minerals and rocks, such as the fireclays, abrasives, ganisters and silica rocks, roadstones and iron ores. The building stones collections have been cleaned and in part revised. A new case has been arranged to show typical examples of Survey maps and memoirs, and the other recent publications of the Survey. The latest edition of the quarter inch map of England and Wales has been mounted and is exhibited on one of the walls. A new edition of the Short Guide to the Museum is now on sale.

Many requests are received from scientific societies, schools and clubs, for demonstrations on the exhibits in the Museum, and, although no official demonstrator has been appointed, these requests are always acceded to. Members of the Survey and Museum staffs undertake the task of providing these demonstrations, often in their private time, and their services must be gratefully acknowledged. The favourite subjects are such as the geology of the London district, or of the south-east of England, the exhibited collections of building stones, roadstones, gems and ores. The attendance at each demonstration is necessarily limited owing to exigencies of space. Fifty-nine demonstrations of this type were given during 1922 and the demand for them is increasing. They undoubtedly have educational value and are much appreciated.

Large additions to the library continue to be made, and the arrears of foreign publications which had been unavoidable during the war are now diminishing. A very large series of maps and memoirs has been obtained from the Geological Survey of

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Prussia, and our set of their publications is now practically complete.

The library is extensively used by geologists, engineers, and travellers, especially for its collection of geological maps and memoirs on regional geology. Lists of the additions to the library are now posted at the entrance to direct attention to the latest publications received. Over five hundred geological maps of all parts of the world were added during 1922.

I.—SURVEY WORK

(1)—ENGLAND AND WALES

Field-work

London District.—Field survey was completed in Sheets 239 (Hertford), 256 (North London), 271 (Dartford), and continued in Sheet 257 (Romford) by Messrs. Bromehead, Dines and Edmunds, with Mr. Dewey as District Geologist.

Shropshire, Warwickshire and Staffordshire District.—Work was completed in Sheets 138 (Wem) and 168 (Birmingham), and continued in Sheets 153 (Wolverhampton) and 167 (Dudley) by Messrs. Pocock, Whitehead, and Robertson, under the superintendence of Mr. Cantrill, District Geologist.

Lancashire District.—Work was continued in Sheet 76 (Rochdale) by Mr. Wright, District Geologist, and Messrs. Sherlock, Wray, Lloyd, Tonks, and Marsden. Small areas in the adjacent Sheets 67 (Garstang), 68 (Clitheroe), and 75 (Preston) were also examined.

Cumberland District.—Work was completed in Sheets 11 (Longtown), 16 (Silloth), and 17 (Carlisle), continued in Sheet 28 (Whitehaven), and commenced in Sheet 18 (Brampton) by Messrs. Dixon, Eastwood, Trotter, Hollingworth, and Tonks, under the superintendence of Mr. Bernard Smith.

Northumberland and Durham District.—The revision was completed of Sheets 1 (Norham), 2 (Berwick), and 4 (Holy Island). Work has been continued in Sheet 3 (Ford) and commenced in Sheets 6 (Alnwick), 9 (Rothbury), 14 (Morpeth), 20 (Newcastle-on-Tyne) by Mr. Carruthers, District Geologist, with Messrs. Dinham, Burnett, Fowler, Maden and W. Anderson.

Indoor Work

The manuscripts of the following memoirs are being written or edited for publication :—

Special Reports on the Mineral Resources of Great Britain :—
Copper Ores of the Midlands, the Lake District, and North Wales.
Refractory Materials : Fireclays. Chemistry and Physical Tests.
Water Supply of Wiltshire.
Water Supply of Gloucestershire.
Water Supply of Dorsetshire.
Soils and Subsoils with especial reference to London and its neighbourhood (3rd edition).
Guide to the Goring Model.
Explanations of Sheets 11 (Longtown), 16 (Silloth), 17 (Carlisle), 108 (Flint), 138 (Wem), 168 (Birmingham), 239 (Hertford), 256 (North London), 271 (Dartford), 318 and 333 (Brighton and Worthing).

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The following maps and memoirs were published or passing through the press in 1922 :—

I.—MAPS

Published.

¼-inch to 1 mile :—

Sheet 15 (Birmingham, Northampton, Gloucester, Oxford, Worcester). New Edition.

1 inch to 1 mile :—

Sheet 154 (Lichfield, drift edition), Sheets 226 and 227 (Milford, drift and solid editions), Sheet 231 (Merthyr Tydfil, new drift and solid editions), Sheet 244 (Linney Head, solid edition, hand-coloured), Sheet 245 (Pembroke, solid edition, hand-coloured), Sheet 249 (Newport, new drift and solid editions), Sheet 255 (Beaconsfield, drift edition).

6 inches to 1 mile :—

Derbyshire, 26 N.W.; 35 N.W.

Staffordshire, 45 S.W., S.E.; 51 N.W., N.E., S.W., S.E.; 57 N.W., N.E., S.W., S.E.; 63 N.W., N.E., S.W., S.E.

Warwickshire, 2 N.E. (Staffs. 59 N.E.), S.E. (Staffs. 59 S.E.); 5 N.E. (Staffs. 65 N.E.), S.E.; 9 N.E., S.E.; 10 N.W., N.E. (Leics. 41 N.E.), S.W., S.E.; 11 S.W. (Leics. 42 S.W.); 15 N.E., S.E.; 16 N.W., N.E., S.W., S.E.; 17 N.W., S.W.; 20 N.E., S.E.; 21 N.W., N.E., S.W., S.E.; 22 N.W., S.W.

In the press, engraving or colour-printing.

1 inch to 1 mile :—

Sheet 96 (Liverpool), Sheet 108 (Flint), Sheet 169 (Coventry), Sheet 238 (Aylesbury), Sheet 271 (Dartford), Sheet 313 (Shaftesbury).

6 inches to 1 mile :—

Cheshire, 30 N.W. and 30A N.E., 30 N.E.

Denbighshire, 20 N.E. (Flint. 16 N.E.), S.E. (Flint. 16 S.E.); 21 S.W. (Flint. 17 S.W.), S.E.

Flintshire, 2 N.W., (2 N.E. and 2A S.E.), S.W., S.E.; 3 S.W.; 5 N.E.; 6 N.W., N.E., S.W., S.E.; 9 N.E., S.E.; 10 N.W., S.W., S.E.; 13 N.E., S.E. (Denbigh. 15 S.E.); 14 N.W., N.E., S.W.; 17 N.W.

Leicestershire, 28 N.W. (Staffs. 60 N.W., Warw. 3 N.W.).

Warwickshire, 3 S.W. (Leics. 28 S.W.); 6 N.W. (Leics. 34 N.W.), 6 S.W.

Copies of the following six-inch sheets, which are not to be published, were deposited in the Library for public reference :—

Cheshire, 22 N.E., S.W., S.E.; 23 N.W., S.W.; 31 N.W.; 34 N.W. (Salt mines information only).

Dorset, 14 N.E., S.E.; 24 N.E. ; and parts of 3 S.E.; 4 S.W.; 7 N.E.; 8 N.W., N.E., S.W., S.E.; 13 S.E.; 14 N.W., S.W.; 22 N.W., N.E.; 23 N.W., N.E.; 24 N.W.

Hertfordshire, 39 S.W.

Lancashire, 106 N.W. (part), N.E. (part), S.W., S.E. (part); 113 N.W., N.E. (part), S.W. and S.E. (part).

Middlesex, 1 N.E., S.E.

II.—MEMOIRS

Published.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1921. 189 pp.; 6 text-figures. 1922. Price 5*s.* net.

Special Reports on the Mineral Resources of Great Britain :—

Vol. II.—Barytes and Witherite. By G. V. Wilson, B.Sc., T. Eastwood, A.R.C.S., R. W. Pocock, B.Sc. D. A. Wray, M.Sc., and

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T. Robertson, B.Sc., with contributions by H. G. Dines, A.R.S.M. 119 pp.; 6 plates; 1 text-figure. *Third Edition.* 1922. Price 3*s.* net.

Vol. XX.—Lead and Zinc. The Mining District of North Cardiganshire and West Montgomeryshire. By O. T. Jones, M.A., D.Sc., Professor of Geology and Mineralogy, Victoria University, Manchester. (*Late of the University College of Wales, Aberystwyth*). 207 pp.; 1 coloured geological map; 27 plates; 4 text-figures. 1922. Price 7*s.* net.

Vol. XXIII.—Lead and Zinc Ores in Pre-Carboniferous Rocks of West Shropshire and North Wales. Part I.—West Shropshire. By Bernard Smith, M.A. Part II.—North Wales. By Henry Dewey and Bernard Smith, M.A. 95 pp.; 13 text-figures. 1922. Price 3*s.* net.

The Water-Supply of Cambridgeshire, Huntingdonshire and Rutland from Underground Sources. By William Whitaker, B.A., F.R.S. 157 pp.; 1 text-figure. 1922. Price 7*s.* net.

The Geology of the London District. (Being the area included in the four sheets of the Special Map of London). By Horace B. Woodward, F.R.S. *Second Edition.* Revised by C. E. N. Bromehead, B.A., with notes on the Palæontology by C. P. Chatwin. 99 pp. 1922. Price 1*s.* 6*d.* net.

The Geology of the Country around Beaconsfield. (Explanation of Sheet 255). By R. L. Sherlock, D.Sc., A.R.C.Sc., and A. H. Noble, M.C., M.A.; with contributions by J. Pringle. 59 pp.; 1 plate; 2 text-figures. 1922. Price 2*s.* net.

A Short Guide to the Museum of Practical Geology, Jermyn Street, London, S.W. 1. 44 pp. *Third Edition.* 1922. Price 2*d.* net.

In the press.

Special Reports on the Mineral Resources of Great Britain :—

Vol. I.—Tungsten and Manganese Ores. *Third Edition.*

Vol. IV.—Fluorspar. *Third Edition.*

Vol. XXV.—Lead and Zinc Ores of Northumberland and Alston Moor.

Vol. XXVI.—Lead and Zinc Ores of Durham, Yorkshire and Derbyshire, with notes on the Isle of Man.

Vol. XXVII.—Copper Ores of Cornwall and Devon.

Memoirs of the Geological Survey of Great Britain :—

Palæontology. Vol. II. Fossil Plants of the Carboniferous Rocks of Great Britain. Parts 1, 2, and 3.

The Concealed Mesozoic Rocks in Kent.

The Geology of Liverpool, with Wirral and part of the Flintshire Coalfield. (Explanation of Sheet 96.)

The Geology of the Country around Coventry, including an account of the Carboniferous Rocks of the Warwickshire Coalfield. (Explanation of Sheet 169.)

The Geology of the Country around Aylesbury and Hemel Hempstead. (Explanation of Sheet 238.)

The Geology of the Country South and West of Shaftesbury. (Explanation of Sheet 313.)

(2)—SCOTLAND

Field-work

West Highlands.—Sheet 42 (Tiree) was commenced and finished, 51 (Coll) was finished and work was continued in Sheet 52 (Ardnamurchan), by Messrs. Richey, Eyles, and A. G. MacGregor under Mr. E. B. Bailey, District Geologist.

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North-East Highlands.—Mr. M. Macgregor, District Geologist, with Messrs. Wilson, Haldane, Ross and Phemister, completed the survey of Sheet 102 (Lairg) and continued that of Sheet 108 (Altnaharra). Messrs. Macgregor, Read, and Haldane also revised parts of Sheet 103 (Brora) with a view to replacing the old hand-coloured map published in 1896.

Ayrshire.—Mr. E. B. Bailey, District Geologist, and Messrs. Anderson, Richey, Eyles, Simpson, and A. G. MacGregor have continued survey work in Sheets 22 (Kilmarnock), and 14 (Ayr).

Lanarkshire (including Muirkirk), Clackmannanshire and Stirlingshire) —Mr. M. Macgregor, District Geologist, and Messrs. Wilson, Read, Haldane, Ross, and Phemister, have continued the revision of Sheets 15 (Muirkirk), 23 (Lanark), and 39 (Stirling).

Indoor Work

The manuscripts of the following memoirs are being written or prepared for publication :—

Economic Geology of the Central Coalfield of Scotland :—
Area VI.—(Bathgate).
Economic Geology of the Ayrshire Coalfield :—
Area I.—(Dalry, Saltcoats, Kilwinning, and Kilmaurs).
Explanations of Sheets 102 (Lairg), 44 (Oban and Mull), 86 and 96 (Portsoy, Huntly, Banff).

The following maps and memoirs have been published or are passing through the press :—

I.—MAPS

Published.

1 inch to 1 mile :—
Sheet 37 (Mid Argyll).

6 inches to 1 mile :—
Ayrshire, 8 N.E.; 11 N.E.; 12 N.W.
Lanarkshire, 8 S.W.; 9 S.W.; 11 N.E.; 13 S.W., S.E.; 14 S.W.; 16 N.E.; 17 N.E., S.W. ; 18 N.E., S.W.; 24 S.W., S.E.; 25 N.W.
Renfrewshire, 7 N.E., S.E.; 11 N.E., S.E.; 12 S.W.; 16 N.W., N.E.; 17 N.W.
Stirlingshire, 25 S.W.; 29 N.E.

In the press, engraving or colour-printing.

1 inch to 1 mile :—
Special Map of Assynt District, Sheet 86 (Huntly), Sheet 96 (Banff), Sheet 84 (Lower Findhorn and Lower Strath Nairn), Sheet 54 (Moor of Rannoch), Sheet 44 (Mull), Sheet 31 (Falkirk), Sheet 16 (Moffat), Sheet 3 (Stranraer, Port Patrick), Sheet 2 (Whithorn, Burrow Head), Sheet 1 (Mull of Galloway).

6 inches to 1 mile :—
Ayrshire, 8 S.W., S.E.; 11 N.W., S.W., S.E.; 12 S.W.; 16 N.W. and S.W., N.E., S.E.; 17 N.W., N.E., S.W., S.E.; 23 N.W., N.E.
Stirling 23 S.E.; 28 S.E.; 29 N.W., S.W.; 33 N.E.

Copies of the following six-inch sheets, which are not to be published, were deposited in the Office for public reference :—

Argyllshire, 21 S.E.; 22 N.W., S.W.; 37 N.W., S.W.
Ayrshire, 49 N.E., S.E.; 70; 73 N.W., N.E., S.E.; 74 N.W., N.E.
Dumfriesshire, 31; 32; 33; 38 N.E.; 39; 40; 47 N.W., N.E.; 48 N.W., N.E.; 49; 55 N.E., S.E.; 60 N.E., S.E.; 61; 62; 63; 64 N.W., S.W.
Kirkcudbrightshire, 27; 31; 32; 33; 34; 39; 40; 41; 44; 45; 46; 47; 49; 50; 51; 52 N.W., N.E., S.W.; 54.

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II.—MEMOIRS

Published.

Summary of Progress of the Geological Survey of Great Britain for 1921. *See* p. 13.

The Ayrshire Bauxitic Clay. By G. V. Wilson, B.Sc. 28 pp.; 1 plate; 2 text-figures. 1922. Price 1*s.* 6*d.* net.

Special Reports on the Mineral Resources of Great Britain :—

Vol. XXIV.—Cannel Coals, Lignite and Mineral Oil in Scotland. By W. Gibson, D.Sc., from contributions by J. S. Flett, F.R.S., E. M. Anderson, M.A., G. W. Lee, D.Sc., and M. Macgregor, M.A., 73 pp.; 6 text-figures. 1922. Price 2*s.*

In the press.

The Geology of the Lower Findhorn and Lower Strath Nairn, including part of the Black Isle near Fortrose. (Explanation of Sheet 84 and part of 94 Scotland).

The Geology of Corrour and the Moor of Rannoch. (Explanation of Sheet 54).

II.—GENERAL WORK

A.—PETROGRAPHICAL DEPARTMENT

In addition to the ordinary routine work of the Petrographical Department Dr. Thomas has been employed mainly on the preparation of a petrological account of Sheet 44 (Mull), which, with the co-operation and assistance of Mr. Bailey, he has now completed. He has furnished a petrological description of the Pre-Cambrian and Post-Cambrian igneous rocks of Nuneaton for publication in the memoir on that district.

The petrology of Sheet 54 (Moor of Rannoch) by Dr. Thomas and Mr. Read has been completed and an account of the rocks prepared for the memoir now in the press.

In co-operation with Mr. Radley, at the request of the Building Research Board, Dr. Thomas undertook an investigation to test methods for determining the proportion of slag in Portland Cement.

During the year a paper by him on the Xenolithic Intrusions of Mull was published by the Geological Society of London.

The Collections have benefited by several presentations. Mr. Shannon presented a collection of igneous rocks with sections from the Torquay district, and late in the year Sir A. H. McMahon gave to the Department the English collection of rocks and sections illustrative of General McMahon's work in the West of England. The registration of this last acquisition is in hand but not yet completed. The additions to the collections of sliced rocks total 539, made up as follows :—English 135, Scottish 377, Irish 5, Foreign 22.

The number of rocks and corresponding sections registered in the collections up to the end of the year are :—

English	12,372
Scottish	21,430
Irish	445
Foreign	2,487
Total	36,734

The rock sections registered during the year total 539, of which 464 were made in the London Office. Of a smaller number prepared in Scotland, 26 have been forwarded to headquarters for registration.

The work of despatching rocks and sections from the London office to officers of the Survey and private individuals for study has been unusually heavy, no less that 686 rocks and 2,862 sections having been dealt with.

Rock specimens were collected during the year to the number of 1,059, from the counties of Argyll, Ross, Sutherland, Ayr, Renfrew, Wigtown, Kirkcudbright; 626 of these were collected from districts in

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which the geologists are surveying; the remainder were collected in connection with the preparation of colour-printed maps to replace the old hand-coloured issues. Rock sections to the number of 346 were made by Mr. Eckford: only a part of this series has yet been registered.

B.—PALÆONTOLOGICAL DEPARTMENT

England and Wales

During the year 4,800 specimens of fossils have been added to the collections, 800 of which were acquired by purchase. Fossil collecting has been carried on principally in Cumberland, Lancashire, Shropshire and the counties near London, in the course of current Survey work. Mr. Pringle has made numerous field-examinations, principally of Cretaceous, Jurassic, and Carboniferous rocks, in connection with the preparation of sheet memoirs. He has dealt with questions relating to water-supplies and has examined materials from various deep borings. The officers of the department have received many miscellaneous enquiries and have carried out palæontological investigations in connection with the preparation of memoirs. They have also been much occupied with editorial work.

Scotland

During the year the number of fossils collected and registered amounted to 2,535: of these 1,072 were collected from borings and natural exposures in Carboniferous rocks and have proved of much service in the identification of horizons in trial borings for coal; 611 fossils were obtained from the Jurassic area of Ardnamurchan, and 20 from the Pleistocene deposits of Ayrshire.

Mr. Tait collected 832 fossils from the Carboniferous rocks of Northumberland, now under revision by the Newcastle unit.

Two new cases have been added to the Survey gallery, Royal Scottish Museum, and the congestion that existed relieved. Progress has been made with the new exhibits of Mesozoic fossils that are now represented up to the Inferior Oolite inclusive.

C.—CHEMICAL DEPARTMENT

During the past year analyses of 23 rocks were made in the Survey laboratory. These included 11 iron ores for a Memoir on the British Sedimentary Iron Ores, and 6 fireclays for the Report on Refractory Materials; the latter report has also been arranged for publication. Of the remaining analysed rocks, one was a sample of Houston Marl, the other 5 being of igneous character.

Mineral separations of 2 samples of orthite were also made and the analyses are in progress.

Examination has been made of a method of cement-testing on samples supplied by the Building Research Board.

Numerous qualitative and partial analyses have been made for officers of the Survey.

D.—PHOTOGRAPHIC WORK

Mr. J. Rhodes during the year has taken 302 views of geological subjects, mainly in the counties of Dorset and Cumberland. Miscellaneous photographs to the number of 55 and 12 enlargements for the Museum have also been prepared.

The number of negatives now registered is as follows:—

English photographs	2,394
Photomicrographs	1,255
Miscellaneous	831
Total	4,480

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From the negatives of English photographs Mr. Rhodes has made 601 prints for incorporation in the Albums deposited for public reference in the London and Edinburgh Offices. Other prints of a duplicate and miscellaneous nature bring the total of prints made to 828.

The arrears in mounting of English photographs have been overtaken. The total number of prints and corresponding descriptive forms mounted during the year are 1,058 and 930 respectively.

In Scotland 28 views of geological interest were photographed in Argyllshire in the one-inch Sheets 51 (Coll) and 52 (Ardnamurchan).

The sale of prints and lantern slides to the public during the year was 369 slides, 70 prints and 2 enlargements.

III.—MUSEUM OF PRACTICAL GEOLOGY

During the year 1922 the total number of visitors to the Museum was 24,054; of these 20,107 visited the Museum on weekdays in the daytime and 2,020 in the evenings; the number of Sunday visitors was 1,927.

Fifty-nine demonstrations to schools and institutions have been given in the Museum throughout the year, the aggregate attendance being 1,246.

The work of expanding the economic collections has been continued. A case has been arranged to illustrate the uses of clay and a complete collection of British fireclays with their products is now on exhibition; the specimens are arranged topographically.

A special case illustrating the recent maps, memoirs and photographs issued by the Geological Survey, is now set up, and a new ¼-inch geological map of England has been mounted and is on exhibition.

The collection of building stones has been cleaned and relabelled and the stored collections in the basement have been put in order.

A new edition of the Museum Guide has been issued and the investigation of the Strathmore meteorite has been completed; a paper on this subject has been published in the Mineralogical Magazine.

In the Mineral Department the cleaning and registration of specimens in the older part of the collection has been continued, Wall-cases 16–22 having been dealt with.

A case has been arranged to illustrate the Bedded Iron Ores of North Wales.

Seventeen divisions of the Horseshoe Case have been cleaned and relined.

In continuation of the investigation of the English Iron Ores, specimens have been collected from a boring at Frodingham and from North Wales. Examination of the material is in progress and methods for the preparation of thin sections of these rocks are being investigated.

The total number of entries in the Mineral Inventory for the year is 554.

The inventory of the Ludlam Collection has been continued, the number of specimens dealt with being 1,671.

The number of members of the public and of officials of other Departments using the Library has shown no falling off.

The additions during the year comprise 172 volumes of independent works, 2,321 volumes and parts of serial publications, 534 maps, not including those bound in the foregoing, and 163 pamphlets.

The presentations to the Library include a number of volumes and pamphlets from the British Rainfall Organization, and from the executors of the late G. J. Hinde, and a further instalment from the library of the late H. B. Woodward.

Geological maps and memoirs to the number of 485, issued during the years 1914–1922, have been received from the Preuss. Geolog. Landesanstalt.

Particulars of the additions to the collection of geological photographs are given in the report on Photographic Work.

JOHN S. FLETT.
Director.

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List of Donations during the Year 1922

Balsillie, D., Esq., B.Sc.—Stalactite of melanterite.

Bosanquet, Prof. R.—A specimen of *Productus auritus* Phill., from the Carboniferous Limestone (D_2) at quarry on Rock Moor Farm, Alnwick.

Brelich, Henry, Esq., A.R.S.M., M.I.M.M.—Specimen of sillimanite from the Khasia Hills, Assam, Northern India.

British Buddhist Mission to Tibet (per G. Knight, Esq.).—A few rock specimens and quartz crystals, and an ammonite from Gyantse, Tibet.

Brown, G. F., Esq.—A specimen of *Micraster cortestudinarium* Goldf., from the zone of *M. cortestudinarium* of Haling Pit, South Croydon.

Chandler, R. H., Esq.—Two specimens of *Cyrena sp.*, from the Woolwich Beds of Shorne Wood, Kent.

Chester, H. W., Esq.—A specimen of oak from the surface peat of Sawtry Fen, 2 miles south of Holme Station, Great Northern Railway, Huntingdonshire.

Clinton, H. G., Esq.—Various minerals from U.S.A.

Collins, H. F., Esq.—A large and varied series of mineral specimens from Mexico, Spain, N. Wales, etc.

Crofton, Cecil F., Esq.—A garnet brooch, and a cross set with cairngorms.

Davis, A. G., Esq.—Three specimens of *Notamia sp.*, from nodule in lower part of London Clay at Norbiton Potteries, New Malden, Surrey.

Dixon, E. E. L., Esq., B.Sc., F.G.S.—100 large specimens showing fissuring of Carboniferous Limestone and entrance of Millstone Grit into fissures at unconformable junction.

Giffard, H. P. W., Esq.—(*See* H.M. Petroleum Department).

Goulborn, Henry, Esq.—Specimen of talc in a vein of verdite.

Graham, His Honour Judge, K.C.—An agate containing water, from South America.

Groves, J., Esq.—A series of 32 slides of *Charophyta* from the Lower Headon Beds of Hordle Cliff, Hampshire. Figured Reid and Groves, *Quart. Journ. Geol. Soc.*, vol. lxxvii, 1921, plates iv–vi.

Hall & Raine, Messrs.—A series of iron oxides used as pigments.

Harvey, Captain (per Dr. H. H. Thomas).—Radio-active material from mine dumps.

Hewetson, R. L., Esq.—A human bone stained with copper; also gold quartz stained with copper and nickel.

Hibbert, Major, D.S.O. (per A. Broughton Edge, Esq.).—A specimen of fibro-ferrite from the Scouriotissa Mine, Morphou, Cyprus.

Higgins, G. L., Esq.—Silicified wood from Egypt.

Kalgurli Gold Mines, Ltd., The.—A series of specimens of gold telluride ore, from Kalgurli, Australia.

Kay, Rev. H., F.G.S.—Two specimens of *Dadoxylon Kayi* Arber, from the Halesowen Sandstone in mineral railway cutting, Witley Colliery, Halesowen, Worcestershire; also specimens of amethyst, barytes, etc., from the Diorite Quarry, Dosthill, Warwickshire.

Kitson, A. E., Esq.—(*See* The Hon. Nana Ofori Atta).

Knight, G., Esq.—(*See* British Buddhist Mission to Tibet).

MacDougall, J., Esq.—A series of gold specimens and of gold-bearing rocks from South America and other localities.

McMahon, Lieut.-Col. Sir A. H., K.C.I.E., C.S.I., G.C.V.O.—A valuable series of rocks and rock sections forming part of the collection of the late General McMahon.

Murray, E. F. O., Esq.—Specimen of apatite with magnetite, from India.

Nana Ofori Atta, The Hon., C.B.E. (per A. E. Kitson, Esq.).—A collection of forty crystals of diamond, from the auriferous fluviatile gravels of the Birrim River, Abomoso, Eastern Akim, Gold Coast, Africa.

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NEAVERSON, E., ESQ.—A spine of echinoid and a specimen of *Pyrina sp.*, from the Cenomanian Limestone of Shenley Hill, Leighton Buzzard.

O'DRISCOLL, FLORENCE, ESQ.—A polished specimen of opal matrix, and a specimen of Famatina Ore.

PARKINSON, J., ESQ.—A series of rock specimens from the Priscilly Mountain, Pembrokeshire.

PETROLEUM DEPARTMENT, THE DIRECTOR H.M. (per H. P. W. GIFFARD) ESQ.).—A sample of crude petroleum from the D'Arcy Well Boring, Dalkeith, Mid-Lothian, N.B.

RAW, F., ESQ., B.Sc.—A series of specimens showing casts of footprints and other impressions, from the Enville Beds in boring at Slade Heath, near Four Ashes, Wolverhampton.

SCOTT, H. KILBURN, ESQ., M.INST.M.M., F.G.S.—A series of samples of iron ores from the Prince Henri Mine, Luxembourg.

SHANNON, W. G. ST. J., ESQ.—Forty-eight microsections and 23 rock specimens from Torquay.

SHEPPARD, T., ESQ., M.Sc., F.G.S.—A specimen of "snakestone" (Ammonite with carved "head") from Whitby.

SWAN, MESSRS. CHARLES, & COMPANY.—Three emerald doublets.

TATHAM, ATHOL, ESQ. (per SIR AUBREY STRAHAN, K.B.E., etc.).—Two specimens of limestone (Ordovician ?), from the Esthonian Oil Field.

THOMAS, F. A. W., ESQ. (MESSRS. WILKENS & DEVEREUX).—A specimen of descloizite, from Oliphantfontein, South-west Africa.

TABLE I

STATEMENT showing the NUMBER OF GEOLOGICAL MAPS and SECTIONS issued by the ORDNANCE SURVEY to AGENTS, etc., during the year ended 31st December, 1922.

Particulars.	United Kingdom.	England.	Scotland.	Total.
TWENTY-FIFTH-INCH TO THE MILE MAP OF THE BRITISH ISLES :—				
Colour-printed	544	—	—	544
QUARTER-INCH TO THE MILE MAPS :—				
Colour-printed	—	822	82	904
Uncoloured	—	—	—	—
ONE-INCH TO THE MILE MAPS :—				
Whole-sheets, Hand-coloured :—				
Solid	—	76	103	179
Drift	—	40	2	42
Colour-printed	—	—	168	168
Quarter-sheets, Hand-coloured :— (Old Series)				
Solid	—	557	—	557
Drift	—	141	—	141
Quarter-sheets, Hand-coloured :— (New Series)				
Solid	—	—	—	—
Drift	—	—	—	—
Colour-printed :—				
Solid	—	54	—	54
Drift	—	1,884	—	1,884
SIX-INCHES TO THE MILE (COUNTY) MAPS :—				
Whole-sheets, Hand-coloured	—	122	23	145
Uncoloured	—	2	—	2
Quarter-sheets, Hand-coloured	—	40	26	66
Uncoloured	—	458	393	851
Horizontal Sections	—	48	1	49
Vertical Sections	—	54	6	60
TOTALS	544	4,298	804	5,646

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1922

I.—INTRODUCTION

By J. S. FLETT, M.A., D.Sc., LL.D., F.R.S.

In the London district most of the area mapped has been to the north and north-east of London and consists of London Clay, Claygate Beds and Bagshot Sands. The superficial deposits of boulder clay, gravel and brick earth have been carefully studied and provide many problems of great interest and complexity. When the revision of the maps of the immediate neighbourhood of London is completed this unit may be transferred to the Aldershot district, which has especial claims for early revision. Water supply questions requiring geological treatment are very frequent in the south-east of England and require constant attention from Mr. Dewey and his staff. Both Mr. Dewey and Mr. Dines have been engaged for part of their time in preparing reports on metalliferous ores, such as those of tungsten, manganese and copper, which are now in the press.

In the Midlands district, of which Mr. Cantrill has charge, mapping has been carried on principally in Shropshire and Staffordshire, in the Birmingham, Wolverhampton and Wem Sheets. Small areas of Silurian and Coal Measures have been revised, including the important Stourbridge fireclay field and the Halesowen, Keele and Enville beds of the Wolverhampton district, which maintain the characters described in previous "Summaries of Progress." The greater part of the ground revised, however, consists of the New Red rocks, which conceal the Carboniferous over a large area. The Glacial drifts of these Midland Counties have many peculiarities, and additions have been made to our knowledge of northern types of erratics (possibly Irish) in the boulder-clays and the outlines of the lakes that covered extensive areas at the close of the Glacial period. In these lakes sands and gravels were deposited often in the form of kames, eskers and terraces. The special features of the post-Glacial history of the drainage and the abandoned stream courses have much interest to students of the local topography.

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In the Lancashire district, Mr. W. B. Wright and his staff have been much engaged in a study of the palæontological succession in the Millstone Grit and Lower Coal Measures along the lines indicated by Mr. Bisat, who has obtained a sequence of goniatite forms in the corresponding beds in Yorkshire. So far as yet tested this sequence holds also in North Lancashire and will serve to confirm or correct the deductions arrived at on stratigraphical considerations and field evidence.

The revision of this ground has generally established the accuracy of the original survey, but it has been possible to arrive at a more thorough knowledge of the succession of the beds and their lateral variations. Much mining information has accumulated since the ground was last mapped; additional coals are now known, and the structure of the area is being carefully investigated. At present mining in this district is not on an extensive scale. The complete detailed succession of the Lower Coal Measures has now been determined and the outcrops of the grit beds of the Millstone Grit are delineated on the revised maps. At present it is not clear how far the names applied to these grits in the various parts of the district are justified, the relations of the "Third Grit" in particular being somewhat doubtful. An interesting example of lateral variation is described at the horizon of the King Mine in the Middle Coal Measures; it is suggested that this is of the nature of a "wash-out."

In the Whitehaven Coalfield further progress has been made in reading the succession of the Carboniferous rocks, which has hitherto not been perfectly understood. The Hensingham Grit is now regarded as belonging to the Carboniferous Limestone Series and forms a valuable and easily recognised horizon. Consequently the thickness of strata ascribed to the Millstone Grit has been reduced. A noticeable feature of that group is the abundance of shales and the comparative scarcity of sandstone or grit. Its upward limit has not yet been clearly defined.

In the New Red rocks of this district the long standing uncertainty regarding the horizon of the "Upper Gypseous Series" has apparently been cleared up, as Mr. Smith and his staff have reached the conclusion that these beds are part of the Stanwix Shales.

Further evidence has been obtained regarding the classification of the Glacial and post-Glacial deposits of the Carlisle, Silloth and Gretna districts and the presence of two boulder clays and two sets of gravel deposits, previously established, is thoroughly confirmed. Eskers, kames and outwash-deltas are a marked feature of the gravel deposits, and are supposed to indicate the existence of large post-Glacial lakes, of which the shore-lines can be traced at elevations of 50, 75, 100, 140 and 200 feet.

A large area of northern Northumberland has now been revised and the one-inch and six-inch maps are being prepared for publication. In the Scremerston district there are considerable reserves of coals, mostly of an inferior quality, which may ultimately prove worth working. The original survey of part

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of this district proved very reliable, but greater accuracy can now be attained in the identification of the limestones and consequently in the interpretation of the structure of the ground, which is to a large extent covered by drift. Owing to the paucity of boring records it is necessary to rely to a large extent on very careful measurement and detailed investigation of natural sections, especially those of the coast-line, but the sequence as a whole is being gradually elucidated. At Shilbottle new information is being obtained regarding the strata associated with the valuable Shilbottle Coal, which has been famous as a house coal for many years. Investigation is now being carried on in the Upper Limestone group in the Howick area and in the valleys of the Coquet and the Font. During the autumn season a start was made with the revision of the Coal Measures in the neighbourhood of Newcastle.

Revision work in the coalfields of Scotland was continued in Ayrshire, Lanarkshire, and Clackmannan. In Ayrshire the ground surveyed was mostly near Sorn, Galston and Stewarton. The Lower Old Red Sandstone of the Sorn district is invaded by a granite mass which has produced extensive contact alteration. There is a conformable passage between the Upper Old Red Sandstone and the Carboniferous, but the volcanic series which occurs near the base of the Carboniferous is much thinner in Central Ayrshire than in North Ayrshire, and the Carboniferous limestones are thin and may rest directly on the Upper Old Red Sandstone.

The Muirkirk Coalfield shows an interesting and varied succession from the Upper Old Red Sandstone upward. At the base of the Carboniferous the Cementstone group is not everywhere present. The limestones and limestone coals are well developed and may be correlated with the sequence in the Ayrshire coalfield to the west and the Douglas Coalfield on the east.

The revision of the Alloa and Bannockburn coalfields is now nearly completed and the new six-inch maps are being prepared for publication.

Considerable progress has been made with the mapping of Tiree, which consists entirely of various types of Lewisian gneiss with a well-known ornamental marble. On the mainland the gneisses of Ardnamurchan are mostly of Moine types and are penetrated by numerous dykes. Further information has been collected regarding the Jurassic rocks of Ardnamurchan and the Cretaceous and Tertiary sediments of Morven.

We are now in a position to formulate conclusions regarding the volcanic structures which form the western peninsula of Ardnamurchan. They provide many analogies to those already known from Skye and Mull, and the concentric arrangement characteristic of certain volcanic areas is exceptionally well illustrated. Cone-sheets, ring-dykes and screens appear in considerable variety and the sequence of rocks from basic to acid is exceptionally complete.

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The great tract of Moine rocks that occupies the interior of Sutherlandshire presents comparatively little diversity and so far as mapped last year is mostly of familiar types. Newer Granites penetrate the gneisses and show resorption or contamination phenomena where they include basic rocks of igneous origin.

The officers in charge of the Palæontological, Petrographical and Chemical Departments have investigated problems arising from the work of their colleagues in the field. Mr. Pringle has acquired new data regarding the palæontology of the Jurassic rocks of Dorsetshire and has visited a number of borings. Mr. Chatwin has been engaged principally on Tertiary fossils from the London area and Dr. Lee furnishes notes on Carboniferous fossils from Scotland and the Jurassic sequence in Ardnamurchan. With the completion of the description of the Tertiary igneous rocks of Mull, Dr. Thomas is in a position to provide a brief synopsis of the magmatic types encountered in that series.

II.—FIELD WORK

(A)—ENGLAND AND WALES

1. London and South-Eastern District

Henry Dewey, District Geologist.

C. E. N. Bromehead, B.A., Senior Geologist.

H. G. Dines, A.R.S.M., A.M.I.C.E.
F. H. Edmunds, B.A. } Geologists.

In the London District mapping has been continued in Sheet 257 (Romford) and the southern part of Sheet 240 (Epping). Mr. Bromehead surveyed the northern part of the London area in Sheet 256 and the survey of this Sheet is complete.

Messrs. Dines and Edmunds carried on the examination of the area between the Lea valley and Brentwood. The principal results of this work are the separation of the Claygate Beds from the London Clay and the more precise differentiation of the superficial deposits. The modifications of the course of the Thames during the Pleistocene period, as indicated by the distribution of the terrace deposits, have been specially investigated by Mr. Dines.

The increased demands for water brought about by new building schemes and the curtailment of supply due to the prolonged drought have led to the sinking of numerous wells, often over 500 feet deep. Among the principal geological results is the proof that the greatest thickness of the Gault known in Kent occurs near Kemsing. A large yield of water has been obtained from the Upper Chalk between Cheam and Sutton where 65,000 gallons an hour are obtained from a 40-inch borehole. The Ashdown Sand has yielded a large supply to Hastings; this is specially interesting as that formation does not rank high among prolific water-bearing strata.

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Mr. H. J. Osborne White completed the manuscript of the memoir on "The Geology of the Country south and west of Shaftesbury," (Sheet 313), in the early part of the year and Messrs. Dines and Hollingworth finished the mapping of the superficial deposits and certain corrections of the Lower Cretaceous and Gault boundaries in that Sheet, preparatory to the issue of a colour-printed edition.

TERTIARY

Mr. Bromehead has surveyed a considerable area in the northern half of the North London Map (Sheet 256). The "solid" formations exposed at the surface are London Clay and Claygate Beds; the separation of the latter subdivision from the main mass of the London Clay makes the map more intelligible by bringing out the high ground and, to a certain extent, the geological structure of the area. Thus the outliers of the Claygate Beds at Stanmore, Elstree, Woodcock Hill, Arkley and Cock Fosters lie along the normal strike of the rocks, some twenty degrees north of east; while those of Highwood Hill, Totteridge and Mill Hill indicate a subsidiary synclinal axis at right angles to the strike. The topographical basin around Edgware, marked by the radial tributaries of the Silk stream, is shown by the semi-circular distribution of the outliers of the Claygate Beds to be also a structural basin. From the economic point of view, again, it is an advantage to have the loams of the Claygate Beds mapped separately from the stiff London Clay; brickpits have been worked in the Claygate Beds at Brockley Hill, Elstree, Arkley and Totteridge. Unfortunately no fossils have been obtained during the survey to show whether the Claygate Beds represent a palæontological horizon or merely a change in the character of the sediment, the loams of one area being contemporary with the clays of another situated nearer the centre of the London Basin.

From the position of the outcrops of the Claygate Beds the thickness of the London Clay proper can be ascertained at a number of points. At one or two of these the figure has been obtained directly from the record of a boring starting in the Claygate Beds; at the majority, however, it has been calculated by comparison of the levels of the Basement Bed in various borings near the boundary of the Claygate Beds. Along the strike the results show a slight thickening towards Hampstead from both directions:—Hanger Hill, Ealing, 300 feet; Willesden Green, 330 feet; Hampstead, 330 to 375 feet; Highgate, 350 feet; Chingford, 280 feet. In the direction of the dip there is a steady thickening towards the axis of the syncline, as the following figures show:—Stanmore, 200 feet; Harrow, 210 feet; Horsenden Hill, 248 feet; Hanger Hill, 300 feet.

Mr. Dines notes that in north-west Essex the Claygate Beds attain a thickness of 60 feet. They occur over nearly the whole area of Epping Forest, and are exposed in Hastings' brickyard at Pole Hill, Chingford, where 20 feet of alternating beds of sand

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and loam overlie the London Clay. The beds vary from four or five inches to upwards of a foot in thickness and enclose ferruginous concretions or boxstones in large numbers. Springs arise at the junction with the London Clay. Small outliers are seen at Pole Hill, Dog Kennel Hill and Havering Grange. In the country lying south of Chipping Ongar Mr. Edmunds observed the effect of rapid stream-erosion in these beds. It has produced narrow and deep valleys at the Coppice, N.E. of Kelvedon Hatch and near Lincolns, south of Coxtie Green.

The Bagshot Sand, as surveyed by Mr. Dines, forms a large outlier at High Beech and is exposed in front of the King's Oak Inn. At Loughton Camp there is another outlier; the beds worked for sand at Turpin's Cave are still exposed in the old pits. At Jack's Hill, north-west of the Wake Arms, another area of sandy loam may be of Bagshot Sand. There are several small pits in loam that is rather more of a clay than the normal Bagshot Sand, but its colour is similar to that of the High Beech outlier. This loam may belong to the base of the Bagshot Sand. If it were grouped with the Claygate Beds there would be an abnormal thickness of that formation at this locality.

PLEISTOCENE

Mr. Bromehead notes that the re-examination of the superficial deposits has not led to any new results of importance. The oldest member of the group, the Pebble Gravel of Stanmore and Bushey, Totteridge, Arkley and Barnet, is chiefly remarkable on account of the restricted distribution of the Lower Greensand chert. Both horny and spongy varieties of this rock are abundant in the gravel at Barnet and Totteridge; it appears to be derived from the southern or Wealden outcrop. At Stanmore and Arkley the chert is absent or exceedingly rare. Yet the gravels of Barnet and Arkley are parts of a continuous spread. The limit of the chert in these gravels has previously been noted by Mr. R. W. Pocock in the ground to the north; he traced it from Little Berkhampstead to Wrotham Park.[1] The other constituents of the gravel, Tertiary flint pebbles, flints and small quartz pebbles, are in no way affected by this dividing line, nor do the levels at which the beds occur show any change. These facts suggest that the chert was brought into the district from the south at some period anterior to the deposition of the gravels in which it is now found, and to the formation of the Thames valley; this period cannot have been earlier than that of the Barton Beds, in which Lower Greensand chert first makes its appearance in the Tertiary strata farther south.[2] The present limit of the chert in the gravels may be taken to indicate approximately the margin of an earlier chert-bearing deposit, of which the age between the above limits cannot be ascertained.

[1] 'Summary of Progress for 1914' (*Mem. Geol. Surv.*), 1915, p. 33.

[2] 'Geology of Windsor and Chertsey' (*Mem. Geol. Surv.*), 1915, pp. 53, 55.

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The Glacial Gravels with Bunter pebbles and other constituents foreign to the Thames Basin are, in this area, easily distinguished from the earlier Pebble Gravel. They are found about the level of 300 feet, while the Pebble Gravel lies above 400, though in the district to the north, Mr. Pocock[1] finds that the Glacial Gravels and the Boulder Clay overlap the older deposit. The well-known Boulder Clay of Finchley has been mapped through Whetstone, about a mile farther north than is shown on the old map, but there are now no satisfactory exposures. The Boulder Clay and accompanying gravels enter the area shown on Sheet 256 between Botany Bay and the present Lea valley, following what probably represents the Lea valley of that period; the downward succession of the Glacial Gravel, Boyn, Taplow and Flood-plain terraces shows that the Lea has been constantly shifting its course to the east in the Enfield and Tottenham reach. Apparently the Boulder Clay did not override the high ground of Hampstead and Highgate; outlying patches of the gravels are found to the south-west of Finchley, bordering both sides of the Brent valley, but no Boulder Clay has been mapped there; probably a patch exists in Hendon village, but it is now impossible to trace its limits; that shown by Hicks[2] in his map of the area is undoubtedly too large.

The river-deposits of the Lea valley were mapped on the six-inch sheets by Mr. J. A. Howe twenty years ago. It is seldom possible to fix exactly the position of the slope which separates the Taplow terrace from the Flood-plain, as it is for the most part masked by the brickearth. Near Green Street, however, it is marked by a small outcrop of London Clay and near Edmonton it was revealed in excavations for a gravel-pit.[3]

Mr. Dines surveyed several areas of boulder-clay in north-west Essex. At Yardley Hill[4] there are three small patches. At Barn Hill, a little to the north, there is a capping of boulder-clay and much of the country between the two hills is covered with *remanié* drift. No boulder-clay has been recognised in the Lea valley south of Yardley Hill. It has been mapped at Woodredon, north of Theydon Bois, north-east of Loughton, and at Chigwell.

Glacial Gravels form the high ground between Woodford and Buckhurst Hill, smaller areas to the west and north, and also at Claybury north of the Asylum. At many localities glacial gravel underlies boulder-clay, but on the northern boundary at Dagnam Park similar gravel lies on boulder-clay. At Loughton cemetery a gravel of abnormal character is associated with boulder-clay and probably underlies it, but the boundaries are concealed. Grave sections vary, but generally show two feet of gravel resting on four feet of buff sandy brickearth, apparently

[1] *Op. cit.*

[2] *Quart. Journ. Geol. Soc.*, vol. xlvii, 1891, pp. 575–584 and plate xxii.

[3] *See* S. H. Warren, *Proc. Geol. Assoc.*, vol. xxv, 1914, pp. 285, 286.

[4] P. G. Thomson, 'Notes on the occurrence of Chalky Boulder Clay at Chingford,' *Essex Nat.*, vol. xviii, 1914–1918, p. 2.

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stoneless, followed by red loamy sand containing, among other constituents, numerous large unworn or slightly rolled Chalk-flints. The deposit was seen to a depth of 6 feet. At 12 feet from the surface the deposit is locally cemented into a ferruginous "pan" four inches to a foot in thickness. Mr. P. G. Thomson found pebbles of the following rocks at this locality,[1]—basalt, Millstone Grit, Bunter sandstone and quartzite, crinoidal limestone and Rhaxella chert.

In the Roding valley some gravel hitherto classed as Glacial Gravel has been included with the terrace gravel of the Roding. The height of these deposits above the river and their general characteristics accord better with the terrace than with the glacial deposits. For instance the gravel at Chigwell, Chigwell Lane station, and part of the gravel south-east of Loughton and south of Theydon Mount have been so mapped. A patch of gravel near Claybury Asylum, previously classed as Valley Gravel, is now considered to be of glacial origin.

According to Mr. Edmunds, some gravel which seems to correspond to the 'Warley group' has been mapped on both sides of the road one mile north of Kelvedon Hatch. Glacial Gravel has been mapped at Langford bottom, 1½ miles south-west of Stanford Rivers, at Standon Massey and at Locksmith Wood, one mile south of Coxtie Green. Some gravels mapped as Glacial on the old map at Navestock Park and south of Stanford Rivers have been divided into river gravel and Glacial Gravel.

An interesting example of incised meanders has been described by Mr. Edmunds. To the north of Stanford Rivers a small stream flows over a deposit of brickearth into which it has cut a series of acute meanders to depths varying from six to eight feet. This brickearth, which may be contemporaneous with the Taplow brickearth, apparently filled a pre-existing valley. Some old excavations in a disused brickyard show that at a distance of 20 yards from the right bank of the stream the London Clay occurs about 3 feet from the surface. It also occurs on the left bank ten yards from the stream. The brickearth extends to the junction of the tributary with the Roding valley, where it spreads out on the right bank of the main valley immediately below the confluence.

2. Shropshire and Staffordshire District

T. C. Cantrill, B.Sc., District Geologist.
C. B. Wedd, B.A. } Senior Geologists.
R. W. Pocock, B.Sc. }
T. H. Whitehead, M.Sc., A.R.C.Sc. } Geologists.
T. Robertson, B.Sc. }

In Shropshire Mr. Pocock has completed the re-survey of the Wem Sheet (138), the area revised extending from Ellesmere on the west to Market Drayton on the east.

[1] 'On the occurrence of Rhaxella Chert in Epping Forest Gravels,' *Essex Nat.*, vol. xvii, 1912–1913, p. 258.

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In Staffordshire Mr. Whitehead has been occupied with the mapping of the extreme south-western portion of the South Staffordshire Coalfield and its borders as far west as Whittington Common and Churchill, in the Dudley Sheet (167), and southward into the adjacent Droitwich Sheet (182). In the Wolverhampton Sheet (153) Mr. Robertson has carried the re-survey of the neighbourhood of Wolverhampton westward as far as Shipley and Patshull, and has completed the portion of the South Staffordshire Coalfield lying between Wolverhampton and Bilston.

SILURIAN

Some small inliers of Silurian rocks fall within the area surveyed near Stourbridge by Mr. Whitehead. One of these is the well-known occurrence at the Hayes, Lye[1], where beds from the Lower Ludlow Shales to the Downton Castle Sandstones are exposed. These beds dip to the east, and are overlain on that side by the coarse basal conglomerate of the Middle Coal Measures. About 100 yards to the west, in a small brook, these basal conglomerates, here not so coarse, were found again, also with an easterly dip. It is clear, therefore, that the Silurian outcrop of the Hayes is terminated towards the west by a fault. In the brook referred to, the Coal Measures conglomerate rests upon hard, highly micaceous purple and green sandstones, and also, a few yards farther north, upon purple and green mottled clays. No fossils were found in these sandstones and clays; but from their lithological characters, and their position relatively to the Coal Measures conglomerate, it seems clear that they are of 'Red Downtonian' (or Ledbury Passage Bed) age. Red Downtonian rocks at this locality appear not to have been hitherto recorded.

Another small exposure of Silurian rocks occurs in Perrin's Lane, near Careless Green, Wollescote. Here Mr. W. King identified the Ludlow Bone Bed in a sewer-trench; but when the locality was visited during the survey, only the unfossiliferous lower portion of the Downton Castle Sandstones was exposed *in situ*. Some highly micaceous green sandstones and purple and green clays occur in Ludgbridge Brook, about 50 yards east of Spring Street. These dip north-westwards, at about 40°, under a coarse Coal Measures conglomerate, and should perhaps be referred to the Downtonian.

Another unrecorded exposure of Downtonian rocks occurs at Coalbournbrook, near Dennis Park, and 700 yards south-west of Brettell Lane Station. Here, underlying the coarse basal Coal Measures conglomerate, there are highly micaceous dark purple and pale green sandstones, dipping eastward at 55°. These sandstones rest on hard dark purple marls, which are

[1] J. B. Jukes, 'The South Staffordshire Coal-Field' (*Mem. Geol. Surv.*), ed. 2, 1859, pp. 107, 154; W. W. King and W. J. Lewis, 'The Uppermost Silurian and Old Red Sandstone of South Staffordshire,' *Geol. Mag.*, 1912, p. 439; W. W. King, 'The Plexography of South Staffordshire in Avonian Time,' *Trans. Inst. Min. Eng.*, vol. lxi, 1921, Figs. 1 and 2, p. 158.

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somewhat micaceous, and have pale green patches. About 50 yards west of this exposure a fragment of green coarse micaceous sandstone was dug up, very similar in appearance to certain of the sandstone beds in the Temeside Shales at Brewin's Bridge, Saltwells.

Fossils collected from the Silurian limestone outcrop at Park Hill (just south of Wolverhampton), in the area surveyed by Mr. Robertson, prove it to be Aymestry. By a mistake in colouring it is represented as Wenlock Limestone on the Old Series One-inch Sheet 62 S.W., though correctly described as Aymestry by Jukes.[1]

CARBONIFEROUS : COAL MEASURES

In the area between Wolverhampton and Bilston Mr. Robertson reports that little alteration has been made in the mapping. The Old Hill Marls are well exposed in the Phœnix clay-pit a short distance north of the Fighting Cocks, and the coals have been worked underneath them. The main fault that throws down the productive Coal Measures against the Keele and Enville Beds must, therefore, lie farther west, probably near the Dudley road.

At Wednesfield clear evidence of the intrusive nature of the dolerite on which the town is built is to be seen in a pit about 100 yards south of the canal bridge at the tramway terminus. Here the igneous rock is overlain by Coal Measures shales, which are baked for about a foot from the junction.

The sandstones of the Enville or Keele Beds, which form the conspicuous ridge on which the public buildings of Wolverhampton stand, can be seen only occasionally in excavations. It is certain, however, that a continuous band of higher Carboniferous rocks extends from Penn Common *viâ* Wolverhampton and Heath Town to Hilton Park.

Near Stourbridge, Middle Coal Measures have been found by Mr. Whitehead to crop out over an area averaging about a mile and a half broad between the Western Boundary Fault and the Hayes Fault. The Lye Station (G.W.R.) lies approximately in the middle of this area, which contains a large portion of the well-known Stourbridge fireclay field. The area includes the southern termination of the Netherton anticline, and another fold, of monoclinal form, of which the axis runs in a north-east and south-west direction in the neighbourhood of Peter's Hill, Amblecote. Between these two arches lies the basin of Hay Green and Hungary Hill. This area of Middle Coal Measures is terminated on the south by a fault, running a little north of east, near Wollescote Hall, which throws down the Halesowen Beds against them.

The Etruria (Old Hill) Marl crops out over the greater part of the area around Cradley, between the Hayes Fault on the west and Coombes Wood on the east.

[1] 'The South Staffordshire Coal-Field' (*Mem. Geol. Surv.*), Ed. 2, 1859, p. 148.

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Halesowen Sandstones, however, occupy Homer Hill and a smaller area at Overend, Cradley, being thrown down to this position by the Cradley Fault. The main outcrop of the Halesowen Beds comes in south of this, and their base can be traced from near Furnace Hill, Halesowen, by Belle Vale and Windmill Hill, to the Hayes Fault near Careless Green. West of this point the Halesowen Beds are cut off to the north by the Wollescote Hall Fault before mentioned.

The Halesowen Beds appear to include at least two fairly persistent coal-seams, of which the lower is that included in his 'Halesowen Coal and Clays' group by Mr. H. Kay.[1] The higher seam is exposed in the dingle immediately south of the old Wassel Grove shafts. In addition, impersistent seams, streaks, and pebbles of coal occur in several localities.

The Halesowen Beds pass gradually into the overlying Keele Beds. The highest beds of the former consist of grey clays, which, followed upwards, become mottled with red and purple until the latter colours predominate. It is in these purple clays that the little coals of Uffmoor Wood, referred to in the 'Summary of Progress for 1920,'[2] occur.

In the stream-course running from the north-east corner of Hagley Wood to Lutley Brook, traces of a Spirorbis limestone have been found in these clays. Similar clays are seen in Wollescote Dingle, west of Hodge Hill. The buff Halesowen Sandstones of Hodge Hill are abruptly truncated some 700 yards south-west of the summit, near where a public footpath crosses the dingle. In the dingle at this point red marls and purple and lavender sandstones, considered to represent the basal beds of the Keele group, dip at a steep angle to the north-west. It is clear that a fault throwing down to the west occurs here. This is believed to run towards Careless Green, near which it and the Hayes Fault, the Wollescote Hall Fault, and another fault running between Oldnall Colliery and Foxcote, all meet. Thus the Hayes 'Fault' proper, which is a down-throw or down-fold to the east, cannot be said to extend south of Careless Green, being here replaced by the Wollescote Dingle Fault, with a downthrow in the opposite direction.

South of Hagley Wood, and in Hagley Park, bands of sandstone and 'pellet-rock' occur, which become increasingly calcareous as they are followed upward. The higher beds, with their interbedded marls, are believed to represent the Calcareous Conglomerate Group of the Enville Beds (the 'Middle Permian').[3] In Hagley Park the highest of these beds contains small pebbles.

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[1] 'On the Halesowen Sandstone Series of the South Staffordshire Coalfield,' *Quart. Journ. Geol. Soc.*, vol. lxix, 1913, p. 442.

[2] *Mem. Geol. Surv.*, 1921, p. 14.

[3] W. W. King, 'The Permian Conglomerates of the Lower Severn Basin,' *Quart. Journ. Geol. Soc.*, vol. lv, 1899, p. 111; *see also* T. H. Whitehead in 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, Appendix vii.

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These beds are followed upwards with apparent conformity by the well-known Clent Breccia, described by Mr W. King.[1] The well-bedded character of this deposit (noted by that author) is worthy of mention. Perhaps the best exposure is that afforded by the stream-section west of Great Farley Wood.

TRIAS

In the neighbourhood of Market Drayton Mr. Pocock finds that the soft red sandstones of the Lower Mottled division of the Bunter are exposed in the valley of the Tern, and are overlain by the Pebble Beds, which are here well developed.

The silicified wood found by Mr. Pocock at Hungryhatton[2] has been examined by Dr. Kidston, who refers it to *Dadoxylon kayi* Arber,[3] a Carboniferous species, and, so far as we know, as yet found in the Staffordian Series alone.

Further examination of the beds in which the wood occurs leaves little doubt that these are Bunter Pebble Beds, and we can only conclude that the fossil wood is derived. It does not seem possible, however, that the logs could have been drifted into their present position if they had already been silicified, as the maximum diameter of the associated pebbles is about one inch, while the logs measure six to nine inches in diameter and up to four feet in length. It is suggested that their silicification was subsequent to their deposition in the Pebble Beds.

The Bunter Beds near Market Drayton are bounded on the west by a continuation of the fault that forms the eastern limit of the Hawkstone area. To the west of this fault Keuper Marl is exposed at many points in the valley of the Tern and between Ternhill and Faulsgreen.

Near Ashford Grange the Keuper Marl is exposed on the east of a fault that brings in the Lias. On general considerations of structure, this fault has been continued to the south-west beneath the drift, to Middle and Great Ness.

No Rhaetic Beds have been found in place around the Lias outlier of Prees, as their outcrop is everywhere concealed by drift.

The base of the Keuper Marl on the western side of the synclinal basin cannot be drawn with certainty, as there the drift has a thickness of from 100 to 200 feet. An approximation has, however, been arrived at on the evidence of a boring at Welshampton, which, after penetrating 192 feet of drift, passed through 248 feet of red marl into red sandstone for 8 feet.

Mr. Robertson finds that on the west side of the Wolverhampton ridge there is a strip of Bunter Pebble Bed sandstones stretching from Upper Penn *via* Goldthorn Hill and Dunstall Park Station (on the Great Western Railway) to Bushbury Hill. This is roughly parallel to the belt of higher Carboniferous rocks between Penn Common and Hilton Park. The junction is imperfectly seen in a gravel-pit on the Colton Hills and appears to be an uncon-

[1] 'Clent Hills Breccia,' *Midland Naturalist*, vol. xvi, 1893, pp. 25–27.
[2] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 34.
[3] *Quart. Journ. Geol. Soc.*, vol. lxix 1913, p. 454.

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formity, but not necessarily a very marked one. This is probably the case at Bushbury also; but in the centre of Wolverhampton a fault separates the formations, and has been proved in excavations at the Market Buildings and elsewhere.

There is a wide stretch of fairly low ground underlain by Upper Mottled Sandstone between this Pebble Bed strip and the Tettenhall and Compton scarp. Just north of Dunstall Park a fault coursing north-west and south-east, with downthrow to the north, brings in Keuper sandstone, and small faulted outliers of the same formation are also to be seen at Dunstall Hill. To the south, Keuper sandstone appears again on the ridge connecting Upper Penn with Lower Penn. This sandstone, which is continuous with that which forms the Orton Hills, is cut off to the east by a fault.

The best exposures of the basement-beds of the Keuper in this area are to be found along the scarp that forms a marked feature from Tettenhall south-westwards by Compton, Perton and Great Moor to a short distance west of The Clive. The succession varies markedly from place to place, but the following typical sections show noteworthy points of resemblance :—

The Clive, Pattingham.	Perton, Wrottesley.	G.W.R. Locomotive Depot, Stafford Road, Wolverhampton.
Fine-bedded non-pebbly soft brown sandstone.	Coarse-grained pebbly brown sandstone.	False-bedded brown sandstone.
Coarse to medium-grained pebbly brown sandstone, 10–12 ft.	Coarse grit with pebbles up to 4 in. in length, 3½ ft. Calcareous pebbly grit with marl-fragments, 6 in.	Calcareous pebbly sandstone with angular marl-fragments, 6 in.–2 ft.
Micaceous purple marl with millet-seed quartz-grains, 2 ft. Fine-grained light reddish-brown sandstone with micaceous marly bands, 4 ft.	Purple sandy marl with millet-seed quartz-grains, 8–10 ft. Possibly a slight gap.	Marly sandstone passing laterally into marl, 2–3 ft.
Reddish-brown to green mottled calcareous marly sandstone with scattered millet-seed quartz-grains, 12 ft., passing downward. Fine-grained brown sandstone, 2–3 ft., passing downward.	Reddish-brown fine-grained calcareous sandstone with millet-seed quartz-grains, 4 ft., passing downward.	Dark reddish-brown sandstone, in some cases calcareous, 10–15 ft. Calcareous sandstone with many quartz-pebbles and marl-fragments, 1–2 ft.
Upper Mottled Sandstone.	Upper Mottled Sandstone.	Upper Mottled Sandstone.

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There are usually three fairly distinct stages in the transition. The Upper Mottled Sandstone passes upwards into a calcareous marly sandstone with millet-seed quartz-grains. This is succeeded in most sections by a definite marly band, which attains a thickness of 20 feet at Lower Penn. Above it comes a coarse pebbly calcareous grit with angular marl-fragments.

These basement-beds of the Keuper are succeeded by pebbly sandstones, which pass upwards through non-pebbly sandstones into finely-bedded marly sandstones. These in turn pass up within a short distance into the Keuper Marl by the intercalation of marly bands. This is well seen at Nurton Hill, Pattingham. The transition is too rapid to make possible the mapping of an intermediate group of Waterstones; nor has any break in the succession been detected.

Near Stourbridge, in the area south and west of the South Staffordshire Coalfield surveyed by Mr. Whitehead, the Lower Mottled Sandstone occurs only to the west of the Bunter Pebble Bed escarpment that forms the line of hills including the Wollaston Ridge and Bunker's Hill. The outcrop of the Lower Mottled Sandstone is bounded on the west by the Stapenhill Fault, which throws down against it the Upper Mottled Sandstone, and, in one place, about a mile west of Wollaston, a small outlier of the basement beds of the Keuper. The Lower Mottled Sandstone is dug for building-sand near the point where the Bridgnorth road crosses the Pebble Bed escarpment of Wollaston, and here shows its false bedding in a striking manner. At this place also the irregular and pockety character of the base of the Pebble Beds is well exhibited. Along this escarpment generally the Bunter Pebble Beds are well consolidated, and include bands of hard conglomerate with a calcareous cement.

On the south and south-west borders of the Clent Hills, on the other hand, where the Pebble Beds rest directly upon the Clent Breccia, the former are usually imperfectly consolidated. The discordance between the Pebble Beds and the Breccia is marked, and in Hagley Park the former appear to overstep the Breccia altogether and to rest on the beds below it.

The Upper Mottled Sandstone outcrop occupies a strip of country extending south-westwards from Stourbridge to Churchill and Blakedown. Smaller patches emerge against the Western Boundary Fault at Old Swinford, Hagley, and near Hollies Hill, Belbroughton. This formation is dug for moulding-sand in the Stourbridge district. The main outcrop of the Lower Keuper Sandstone extends from Stourbridge, where it meets the Western Boundary Fault just south of the River Stour, southwards to Belbroughton and beyond. The basal beds consist usually of 2 or 3 feet of dark-red or chocolate-coloured marl, followed by a calcareous breccia with pellets of marl and, in places, pebbles ('catbrain'). Both the marl and the catbrain are seen in the faulted outlier west of Wollaston referred to above.

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JURASSIC

The southern part of the outlier of Lias at Prees has been mapped by Mr. Pocock. As the Lower Lias is almost entirely concealed by drift, its base has been drawn solely on consideration of dip and assumed thickness. The record of a boring near Wem Station appears to indicate a thickness of more than 80 feet of Lias; but as this was a percussion boring and no samples were obtainable, we cannot place much confidence in the record. If this is Lias it may possibly be brought in by faulting.

The top of the Lower Lias is exposed near the base of Prees Hill. Middle Lias forms the hill itself, and is about 100 feet in thickness. The small exposure of Lias against the fault near Ashford Grange is also thought to belong to the Middle division. Upper Lias appears to be absent at Prees; an exposure at the highest point of the hill yielded fossils characteristic of the upper beds of the Middle Lias.

GLACIAL AND POST-GLACIAL

In the area mapped by Mr. Pocock the drift attains a thickness approaching 200 feet near Ellesmere. It is of moundy morainic type, with large meres and peat-mosses in the hollows. The most important of the peat-mosses is Whixall Moss, where there are extensive diggings for peat.

Between Whixall Moss and Edstaston, stiff boulder-clay forms the surface, and the thickness of the drift is not known.

Over Prees Higher Heath and round Prees Hill there is a wide area of sand and gravel with a fairly flat surface rising to nearly 300 feet above Ordnance Datum. These deposits can be followed eastwards in a wide belt to Bletchley, where they are cut through by a north-and-south valley, on the east of which they extend to Little Drayton. The sands are believed to have been deposited under lacustrine conditions at the close of the Glacial period, there being evidence of a shore-line, at a level slightly below the 300-foot contour, that can be traced at intervals over a large part of the area of the Wem Sheet. The lake described by Mr. Dixon in the Newport district[1] is, therefore, thought by Mr. Pocock to have covered a large part of the North Shropshire plain.

An interesting case of river-capture has been brought out by the mapping of the valley of the River Tern. A broad north-and-south valley enters the area of the Wem Sheet (138) near Longslow. The river Duckow, a small stream, enters this valley on the west near Longford and flows northward to join the Weaver. About a mile and a half farther south the Bailey Brook enters the valley on the west and flows southward to join the Tern. In the broad alluvial flat between these two streams, at a height of about 220 feet above O.D., is the watershed

[1] 'Summary of Progress for 1919' (*Mem. Geol. Surv.*), 1920, p. 17; and for 1920' (1921), pp. 19, 20.

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between the Mersey drainage to the north and the Severn drainage to the south. There is little doubt that this valley held the original River Tern, its head-waters having been captured subsequently by the Weaver. The present Tern, which flows past Market Drayton, joins the main valley on the east near Ternhill.

In the coalfield between Wolverhampton and Bilston Mr. Robertson finds that there is not a great deal of drift. The drift-filled river-channel described by Dr. Gibson[1] has been traced from Moxley northwards as far as the canal between Wolverhampton and Willenhall; but beyond that point there is no information regarding it. It maintains its comparatively narrow, steep-sided character throughout. North of the road between Wolverhampton and Willenhall most of the ground is covered with stony clay drift. The Wednesfield sill, however, is free from drift in the northern portion of the town, and the Pebble Beds of Bushbury Hill rise out of lower drift-covered ground. A sheet of clayey drift covers most of the ground on which the town of Wolverhampton is built, except the top of the ridge that extends from Goldthorn Hill to Oxley. Oxley Manor estate is covered with more gravelly material, and so is the area between Merry-hill and the Penn ridge. A tongue of drift, in part clayey, in part sandy and gravelly, extends round the west end of this ridge by Dimmingsdale towards the Smestow Brook valley at Trysull. Farther west, as far as Patshull and Rudge, the country is practically drift-free. A few small patches of gravel occur on the higher ground, similar to those found by Dr. Sherlock and Mr. Dewey in the ground to the north.[2]

Ice-borne boulders of all sizes are to be found in the Wolverhampton area. They are seen most commonly on the higher drift-free ground; but this is probably due to the fact that on the lower ground they are more easily concealed by surface-deposits and do not stand the same chance of having the drift around them washed away. The frequency with which large boulders are found in excavations in the clay supports this view. Nevertheless, there is a fortuitous concentration of boulders in some places. A small area to the north-west of Bradmore has yielded a great number of erratics, many larger than two feet cubes, of both Scottish and Lake District granites and of Welsh volcanic rocks. Mr. Dewey[3] noted the occurrence of similar boulders in the sand-pits between Compton and Lower Penn. At the north-west end of Abbot's Castle Hill, along the back of the scarp, large boulders of Criffel granite are exceedingly numerous. Erratics are not common along the Keuper Sandstone scarp between Shipley, Rudge, and Patshull High Park. At many of the farms, especially in the neighbourhood of Trescott, boulders have been collected from the surrounding land

[1] 'Summary of Progress for 1912' (*Mem. Geol. Surv.*), 1913, p. 31.
[2] 'Summary of Progress for 1915' (*Mem. Geol. Surv.*), 1916, p. 17.
[3] 'Summary of Progress for 1915' (*Mem. Geol. Surv.*), 1916, p. 17.

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and placed around or near the farm buildings, frequently to form walls.

An examination by Dr. Thomas in 1912 of certain specimens collected by Dr. Codd of Wolverhampton from the neighbourhood of Barnhurst and Palmer's Cross (between Wolverhampton and Codsall) showed the presence of granites from Criffel, Dalbeattie, and Eskdale, of granophyre from Ennerdale, and of Welsh volcanic rocks. Around Wolverhampton itself both Welsh and northern erratics occur, but the latter appear to predominate greatly. South-west of the town also, in the Smestow valley, the greater number of erratics appear to be northern ones, and amongst these by far the most common is the Criffel granite. The following list gives the types of erratics from distant sources, with, where possible, their derivations.[1] The more abundant are placed first :—

Northern.	Welsh.
Criffel granite.	Arenig lavas and ashes.
Ennerdale granophyre.	Grits.
Dalbeattie granite.	Trachyte.
Eskdale granite.	Keratophyre.
Lake District volcanic rocks.	Diabase.
Analcite basalt, S.W. Scotland.	Dolomitised Carboniferous limestone.
? Troctolite.	
Rhaetic limestone.	
Liassic limestone.	
Chalk flints.	

The Humber-Severn watershed passes through the town of Wolverhampton, and at Aldersley, north of Tettenhall, there is a well-defined gap (Fig. 1). It has steep sides and is about 100 yards broad at the bottom. In the later phases of the Glacial period this must have been the channel by which great quantities both of water and of rock-material passed into the head of the Smestow valley, and indications of what happened at that time are to be seen lower down the valley. The position of the gap itself is probably due to a fault that courses along the north side of Dunstall Park and brings Keuper Sandstone on the north against Upper Mottled Sandstone on the south. The soft Upper Mottled Sandstone made it more easy for denudation to produce a channel at Aldersley than would have been the case in the Keuper Sandstone to the west or in the Pebble Bed sandstones to the east.

The low Upper Mottled Sandstone country south of the gap is mainly covered with drift, chiefly clayey in character. It becomes more sandy, however, as the Penn ridge is approached, and on the north side of this ridge there are banks and mounds of gravel and sand. The Smestow Brook skirts this drift-covered area

[1] *See* F. W. Martin, *Proc. Birmingham Phil. Soc.*, 1888, pp. 93–118, and 1889, pp. 85–113; also W. J. Harrison in 'The Geology of the Birmingham District,' *Proc. Geol. Assoc.*, vol. xv, 1898, pp. 400–408.

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on the west, running parallel to the Tettenhall–Compton scarp as far as Wightwick, and then rounding the western end of the Penn ridge. This ridge appears to have acted as a barrier against

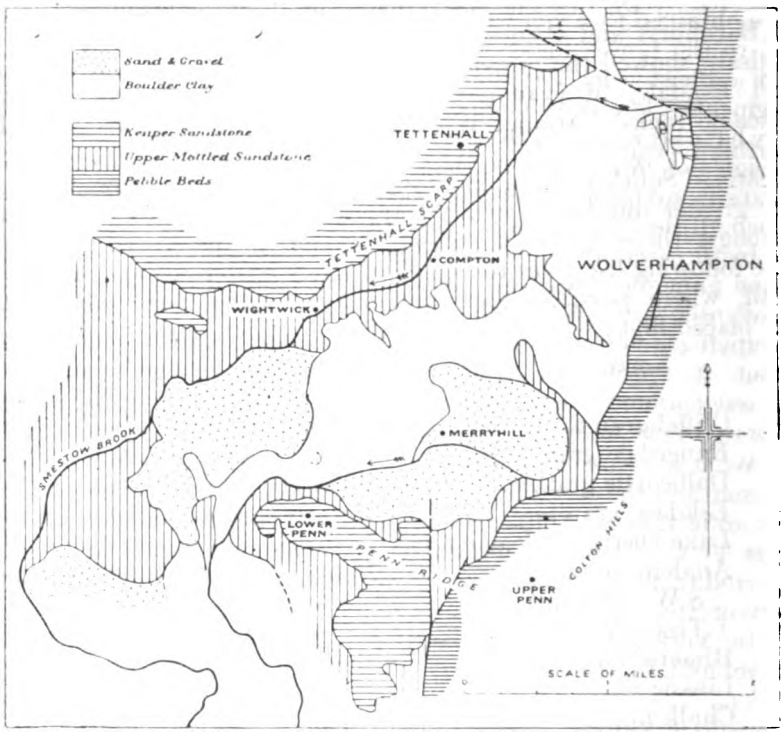

FIG. 1.—*Geological Sketch-map of district west of Wolverhampton.*

which much sand and gravel was banked. The water of the main sub-glacial, and afterwards of the late-glacial, drainage, hemmed in on the south by this ridge, on the east by the Wolverhampton-Penn ridge, and on the north-west by the Tettenhall scarp, flowed out westwards *via* Trescott and thence south to Seisdon, in the course at present occupied by the Smestow Brook. An interesting relic of the old, probably sub-glacial, drainage is to be found in the sand-pits south-west of Compton, where channels filled with sand and gravel run parallel to the main stream-channel at various heights above the present stream-bed, as noted by Mr. Dewey.[1]

Where seen in cross-section the best examples of these channels show a distinct deepening on the lower side, and are of such a shape as to postulate either marginal or sub-glacial streams.

Mr. Dewey also describes the beds that were exposed in the railway-cuttings between Tettenhall and Lower Penn and the esker-like ridges, near Langley Farm, that mark the course of the drainage round the end of the ridge from the *cul-de-sac* between Merryhill and Penn. The moundy character of this dead-end makes it probable that it has been little disturbed since, towards

[1] 'Summary of Progress for 1915' (*Mem. Geol. Surv.*), 1916, p. 17.

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the end of the Glacial period, a mass of ice was left in it and gradually melted away *in situ*.

In a sand-pit just north of Langley Farm a great variety of erratics was found, including many Liassic rocks. Specimens were obtained that can with confidence be referred to the Rhaetic and to the Lower Lias. Flints with shell-casts are also present, and a Pleistocene *Turritella* was found, along with other shell-fragments. It is possible that the Rhaetic and Lower Lias erratics may have been derived from beds that occur at Prees, in Shropshire, though not now exposed; but the presence of Cretaceous rocks makes it advisable to assume their derivation from some area in which all the rock-types are present, *e.g.*, the north of Ireland.

In the area about Stourbridge and Churchill, Mr. Whitehead found numerous patches of gravelly and sandy drift. One of the most interesting of these is the deposit of pebbly sand and loam occupying a terrace-like feature on the north side of the River Stour at Amblecote, about 30 feet above the river. In this deposit mammalian remains (preserved in the Stourbridge Public Library) were found at Mills Meadow Amblecote.[1]

What appears to be a portion of the same terrace-like deposit lies south of the River Stour, near Prestwood. It is here some 10 feet lower than at Amblecote, but at about the same height above river-level. The sand and gravel at canal-level, near Bell's Mill, referred to in the 'Summary of Progress for 1920,'[2] is probably also part of this deposit.

In Norton Covert some sand-pits afford a good exposure in gravel and in laminated sand with lenticles of clay and loam.

The gravels contain many erratics, amongst which were recognised Ennerdale granophyre, ashes and rhyolites of North Welsh type, Rowley basalt, and a fossiliferous fragment containing *Glyptocrinus sp.*, *Orthis retrorsistria*, and *O. vespertilio*. For this fragment Mr. J. Pringle suggests a derivation from the Teirw Beds[3] of the Glyn-Ceiriog district (Denbighshire).

The beds of Norton Covert are very much like those forming the 'Kingswinford Esker'[4], and may well have had a similar origin. At the road east of Norton Covert the base of the drift is about 320 feet above O.D.; but, followed in a south-eastward direction, it rises steadily until on the high ground north of The Birches it reaches about 450 feet. It is likely, however, that the higher ground is covered by a drift deposit of separate origin from that

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[1] W. S. Boulton, 'Mammalian Remains in the Glacial Gravels at Stourbridge,' *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xiv, 1916–17, p. 107.

[2] *Mem. Geol. Surv.*, 1921, p. 22.

[3] *See* T. Groom and P. Lake, 'The Bala and Llandovery Rocks of Glyn Ceiriog (North Wales),' *Quart. Journ. Geol. Soc.*, vol. lxiv, 1908, p. 551, and L. J. Wills and B. Smith, 'The Lower Palæozoic Rocks of the Llangollen District,' *Ibid.*, vol. lxxviii, 1922, p. 179.

[4] W. S. Boulton, 'An Esker near Kingswinford, South Staffordshire,' *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xiv, 1916–17, p. 25, and 'Summary of Progress for 1920' (*Mem. Geol. Surv.*), 1921, p. 21.

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of Norton Covert, but it is impossible to draw a boundary between them on the map.

Farther south, about Stakenbridge, Churchill, and Blakedown, there are several patches of sand and gravel, and much of the intervening ground is covered by thin ill-defined spreads of pebbles and pebbly sand, probably representing *remanié* or downwashed drift. The patches of sand and gravel appear not to lie on a plane surface, though there is a gradual, but irregular, fall in their level from north to south. West and south-west of Blakedown the drift forms two well-marked banks, one at about 300 feet and the other at about 240 feet, separated by a flat shelf-like feature. On Barnett Hill (Sheet 182), however, the base of the drift sand and gravel lies at about 360 feet. The Stour valley above Stourbridge is free from drift, as is also the country to the south, including the Clent Hills west and north-west of Romsley Hill, and most of the ground around Hagley, Holy Cross and Broom. At Madley Heath (Sheets 182 and 183), a ridge about 1½ miles long, topped by drift gravel, trends north-east and south-west from a point about 500 yards south of Dayhouse Bank. On and about this ridge numerous erratics occur. Amongst these were found ashes, rhyolites, and slates of North Welsh type. In addition, boulders and fragments of a cream-coloured quartzose sandstone are rather common. In a fossiliferous fragment of this rock Mr. Pringle has identified *Spirifer bisulcatus* and *Pugnax pleurodon*. He suggests that the rock is derived from the Cefn-y-fedw Sandstone ('Millstone Grit') of North Wales.[1]

Near the village of Broom there is a deposit consisting largely of breccia-fragments, with an admixture of Bunter pebbles, in a sandy matrix. This 'breccia drift,' which seems nowhere to be more than 3 feet thick, is dug for gravel near Field House, building-sand being obtained from the same pit from the Keuper Sandstone beneath. The surface of the ground occupied by this deposit is nearly flat, and falls from a little over 400 feet to a little over 300 feet in about a mile from east to west. On the south the eastern portion of the deposit extends to the foot of a ridge formed by Keuper sandstone and conglomerates, whilst farther west it reaches to the edge of an incipient drainage-channel that runs down to the brook in Broom village. On the north the deposit is bounded by the stream that emerges from the Clatterbach valley, between Clent and Walton Hills. From Field House downwards this stream is markedly entrenched, and the 'breccia drift' extends to the upper edge of the bank formed by the entrenchment. On the north side of the stream there is in one place a flat terrace-like feature, corresponding in level with that on which the 'breccia drift' rests, but upon which this deposit was not found. A small patch of the deposit was, however, found on the north side of the stream near where it crosses the Hagley-Worcester road. It is here at 297 feet, which is lower than any part of the main spread.

[1] *See* 'Summary of Progress for 1914' (*Mem. Geol. Surv.*), 1915, p. 10.

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The accumulation of this ' breccia drift ' deposit evidently took place when all the main topographical features of the district had attained their present form, but apparently before the entrenchment of the local stream-courses. The connection of the deposit with the Clatterbach valley seems clear, and it may well have originated as an outwash from that valley at a time when a greater annual rainfall than obtains at the present day produced a more vigorous stream-action amongst the Clent Hills.

Similar deposits were found at Lower Clent, at from 450 to 500 feet, and at Pedmore, at about 380 feet. That at Pedmore is as much as 5 feet thick in one place, and contains a considerable admixture of clayey material in the matrix. Traces of similar material were found here and there south of Holy Cross.

The spread near Broom is probably the oldest, and may perhaps be of early post-Glacial date; but in other places the material seems to graduate into the modern talus from the Clent Hills, so that it may have been in course of formation, with diminishing vigour, from early post-Glacial to recent times.

It is probable that the spread of red marl ' wash,' which in the neighbourhood of Hagley Wood and Hayley Green is so thick, and so completely masks the subsoil that it has been mistaken for ' Permian ' or Keele Beds *in situ*, had an origin analogous to that of the ' breccia drift ' above described.

3. Lancashire District

Headquarters : Manchester

W. B. Wright, M.I.M.E., District Geologist.
R. L. Sherlock, D.Sc., A.R.C.Sc., Senior Geologist.
D. A. Wray, M.Sc.
W. Lloyd, B.Sc.
F. Marsden, M.Sc.
L. H. Tonks, M.Sc.
} Geologists.

The re-mapping of one-inch Sheet New Series 76 was continued. Mr. Wright was largely occupied in the correlation of the grits and marine bands, and in examination of bore-holes, but surveyed some ground to the north of Bolton. Dr. Sherlock continued mapping in the Accrington area, and Messrs. Wray and Lloyd carried on their work between Burnley and Rochdale. Mr. Tonks surveyed for a short time to the west of Burnley, and Mr. Marsden was occupied in the neighbourhood of Blackburn.

Coal Measures and Millstone Grit of the Rossendale District

Considerable success has attended an attempt at zonal subdivision of the Lower Coal Measures, the Millstone Grit Series and the beds beneath the Kinderscout Grit along the lines indicated by Mr. W. S. Bisat at the Hull Meeting of the British Association in 1922, and the succession of goniatite forms

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established in Yorkshire has been found fully developed throughout the Rossendale anticline. Mr. Bisat has greatly facilitated this work by unreservedly placing at the service of the Lancashire unit his unpublished knowledge of the Yorkshire succession, and, as the publication of his results is pending, a detailed account of the palæontology would be premature in view of the fact that many of the species to which reference would have to be made are as yet undescribed. In the better exposed portions of the ground the palæontological succession has been found to hold without appreciable change in spite of considerable lithological variations, and the constancy of its development is such as to ensure confidence in its application to the interpretation of areas which are badly exposed or much complicated by faulting.

Through the courtesy of Mr. Lomax, microscopist to the Lancashire and Cheshire Coal Research Association, who has allowed a collection to be made from the bullion-material obtained by him from the roof of the Upper Foot Coal, it has been possible to make a thorough examination of the relations of the three forms of Gastrioceras found in this bed. The results arrived at confirm and to some extent amplify the observation of Haug[1] that these forms pass one into the other. The numerous specimens obtained were sorted into series of approximately equal size, and in each series a perfect gradation of form was proved from *Gastrioceras coronatum*, Foord and Crick, on the one hand, through *G. listeri* Auctt. to *G. carbonarium* v. Buch on the other. From a diameter of 15 mm. upwards *G. carbonarium* is the dominant form, while among the smaller sizes it is *G. listeri* that bulks largest. The proportion of *G. coronatum* is never great, but increases with decrease of size. The largest true *coronatum* observed was 23 mm. diameter, but there is some approach to the form up to 30 mm.

On breaking back a number of suitably weathered specimens it was found that *G. carbonarium* passes through a *listeri* stage in its early whorls and in its very earliest approximates to *coronatum*,[2] while *G. listeri* has an early *coronatum* stage. The young stage of *G. coronatum* itself is an extreme form of that species, with an umbilicus almost equal in diameter to the shell, a marked crown of tubercles and an extremely low ventral arch.

An ontogeny of this nature might be regarded as indicating that the ancestor of the group was of the *coronatum* type, and that on lower horizons this form might be dominant. Unfortunately the state of preservation of the goniatites in the marine bands immediately below the bullion-bed has hitherto prevented any accurate investigation of this question. The band at the base of the Lower Coal Measures shows only mere ghosts of some form of *Gastrioceras*, while that between the Rough Rock and the Hasling-

[1] E. Haug, 'Études sur les Goniatites,' *Mémoires de la Société géologique de France*, No. 18, 1898, p. 103.

[2] This relation is indicated by Foord and Buck in the figure on p. 230 of the 'Catalogue of the Fossil Cephalopoda in the British Museum, Part III,' 1897.

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den Flags, while it yields numerous large crushed internal casts of highly tuberculated and widely umbilicated forms suggestive of *listeri* and *coronatum*, has afforded up to the present no specimen with the ornament well enough preserved to make a comparison possible on any other lines than that of general form. Moreover, other undoubtedly distinct species of *Gastrioceras* are found in this bed, so that as yet there is incomplete evidence as to the ancestry of these forms.

BOLTON AREA

Middle Coal Measures were found here by Mr. Wright considerably to the north of their supposed limit, being let down between two north-west faults in the neighbourhood of Bradshaw and Eagley, where they are exposed in the stream sections. A corresponding area of Lower Coal Measures was proved between the same faults extending up the Eagley Brook beyond Dunscar, the Rough Rock crossing the valley above Egerton, and being well exposed in Delph Brook and the lower part of Longworth Clough. The Haslingden Flags are poorly developed in this district and no longer afford a clue to the interpretation of the ground, but at the head of Longworth Clough near Belmont some beds were discovered which from their fauna must be a short distance above the Third Grit. It is probable, therefore, that the coarse pebbly grit exposed in Belmont may be the Third Grit and not, as its lithological character might lead one to suppose, the Kinderscout.

ACCRINGTON AREA

Between Blackburn and Accrington a wide and much faulted trough of Lower Coal Measures is bounded on the south by a large fault bringing up Millstone Grit, and on the north by a sharp fold ranging south-west to north-east and bringing up the Millstone Grit at high dips.

Millstone Grit.—In this area, brought up by the sharp fold mentioned above, between Blackburn and Wilpshire to the west, and Rishton and Great Harwood on the east, the First Grit or Rough Rock is notable for the poor development of the part overlying the Sandrock Coal. Near Rishton this part is represented by about four feet of sandstone. The Second Grit (Haslingden Flags) is well developed west of Rishton and has been extensively quarried at Cunliffe and Close Brow quarries. The base of the rock is a massive sandstone, used for setts.

Below the Haslingden Flags is about 25 feet of greenish concretionary mudstone, which passes down into black shale with ironstone bands; this contains a marine band. In the stream bed towards the north-east of the Close Brow quarry is seen a thin coal with a 3-foot fireclay resting on more shale and this on grit. The Harper Clough quarry then takes up the succession. At the entrance to the quarry a coal-seam crosses, and below it is soft grit, which passes down through well-bedded sandstones into shale containing a marine band. A few feet below

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the band is a 7-foot sandstone with shaly flags below. Then comes a six-inch coal with about 4 feet of fireclay beneath, and about 11 feet of strata showing a transition to flagstones. Not many yards behind the quarry are crags of grit with some pebbles, the commencement of a series of grits, sandstones, and shales, extending downwards to the top of the Pendleside Series.

Lower Coal Measures.—It has been found that, between Accrington and Blackburn, and from Haslingden to Great Harwood, the Lower Coal Measures undergo but small variations. They have been mapped in considerable detail, and the various coal-seams, sandstones, and shales are shown separately on the six-inch maps. As most of the area is buried under drift and much is also built over, it is necessary in many places to rely upon information obtained from records of borings. Fortunately in the Accrington area these are numerous, and we are greatly indebted to the colliery companies and to Mr. J. Spencer, F.G.S., for the details.

In the Accrington area the general succession of the Lower Coal Measures is as follows. Below the Arley Mine there is :—

	Thickness. Feet.	Total. Feet.
Fireclay	5	5
Shale	44	49
Sandstone	37	86
Shale	104	190
Sandstone (Hambledon Scout or Coppice—Old Lawrence of Burnley).	104	294
Mudstone (Accrington mudstone)	100	394
Shale, black	25	419
Sandstone	52	471
Shale, black	112	583
Pasture Mine, to	3	586
Fireclay	2	588
Sandstone (Flag and Slate Rock or Crutchman Sandstone).	60	648
Shale, black (Book-leaf Shale)	75–90	723–738
Cannel Coal, to	1	724–739
Fireclay	4	728–743
Sandstone (Icconhurst Rock)	30	758–773
Upper Mountain Mine (40 yards Coal, Old Robin, or Yard Mine).	2½	760–775
Fireclay	1	761–776
Sandstone and grit (Warmden Rock)	42	803–818
Inch Mine or Fireclay Clay	1½ ins.	
Fireclay	2½	805–820
Shale, black (Dewhurst Shale)	54	859–874
Upper Foot or Bullion Mine	9 ins.	860–875
Fireclay	9 ins.	861–876
Sandstone (Great Arc or Bottom Rock)	27	888–903
Shale	27	915–930
Lower Mountain Mine or Gannister Coal	2½	917–932
Gannister and Fireclay	3½	921–936
Devil's Den Coal, very local		
Fireclay	3	924–939
Shale	25	949–964
Lower Foot Coal	9 ins.	950–965
Fireclay	2	952–967

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	Thickness. Feet.	Total. Feet.
Shale	75	1027–1042
Bassey, or Salts Mine, or Shale Bed Coal	2	1029–1044
Fireclay	1	1030–1045
Sandstone (Woodhead Hill)	63	1093–1108
Shale	65	1158–1173
Ten-inch Coal	10 ins.	1159–1174
Fireclay	4	1163–1178
Shale	6	1169–1184

Of these divisions the four main sandstones can generally be recognised by their lithological characters. The Hambledon Scout Rock is a flagstone closely resembling the Haslingden Flags (2nd Millstone Grit) and, like that rock, succeeds a greenish mudstone. The Crutchman Rock is typically highly micaceous and has been extensively worked for flags and for roofing houses. The Warmden Rock, though in part flagstone, is frequently a grit, and could be mistaken for Millstone Grit. The Woodhead Hill Rock is a typical buff Coal Measures sandstone. All are current bedded.

The Accrington Mudstone is the raw material of an important brickmaking industry. The bricks made are of first-rate quality and are of a bright red colour.

Of the coals, only the Lower and Upper Mountain Mines are worked. The Upper Foot is well known as the source of the famous fossiliferous bullions so well known to palæobotanists. Below the coal there are coal balls, which contain plants still showing the microscopical structure, while above the coal the bullions contain goniatites and other marine fossils.

The area is traversed by numerous faults, and while the majority of them are normal, some have a reversed throw.

Towards the north-west the Lower Measures are brought up by the monoclinal fold referred to above, and rest at angles of from 45 to 50 degrees. It is in this region that the strata below the Lower Mountain Mine are best seen.

Middle Coal Measures.—In the Calder valley the lower part of the Middle Coal Measures exists under drift in a shallow syncline. The Arley Mine has been worked out in the area examined, *i.e.*, north of Hapton and Clayton-le-Moors.

Glacial.—The separation of Glacial Sand and Gravel from Boulder Clay offers considerable difficulties. The greater part of Great Harwood is built on sand and gravel. In the quarries at Rishton terminal curvature is well shown and proves that the ice came from a northerly direction. Striæ have not been found.

BURNLEY-TODMORDEN-ROCHDALE AREA

The area surveyed by Messrs. D. A. Wray and W. Lloyd comprises a belt of Coal Measures and Millstone Grit several miles wide, extending from Burnley through Todmorden to Rochdale. The ground is chiefly moorland, deeply cut by the Cliviger and Walsden gorges; and though for the most part bare and sparsely

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inhabited, the moorland, as a gathering ground for several important water supply schemes, is well worthy of economic mention. In former times the mining of several coal-seams centred an extensive industry on some of the moors, especially in the south, but the getting of coal is now confined to more or less deep workings, chiefly around the towns of Burnley and Rochdale.

The whole area is bounded on the east by the axis of the Pennine anticline; but whereas the district from Todmorden to Rochdale is in a broad sense a N.—S. syncline (complementary to the Pennine anticline) with a considerable pitch to the south, the ground N.W. of Todmorden shows a prevailing westerly dip in the beds. In the latter case, however, the succession of higher beds in a westerly direction is broken by a pair of faults which, diverging towards Burnley, let in a wedge-shaped trough of Middle Coal Measures between Holme and Burnley.

Steep westerly dips characterise the Lancashire side of the Pennine anticline, in contrast with the low easterly dips on the Yorkshire side; in other words, the fold is here monoclinal rather than anticlinal. The 'Anticlinal' fault to which great tectonic importance was ascribed by Hull,[1] has been shown to be of relatively minor effect in this region, for it has been possible in many places to trace an apparently unbroken succession across the western limb of the anticline. The main line of fractures lies more to the west.

While the mapping of the original survey has in a broad sense held good, certain modifications have been effected. The sandstones of the Lower and Middle Coal Measures have been mapped for the first time. Recent information from borings, collieries and outcrop workings has been utilised to modify the outcrop lines of various coal-seams; several additional seams, chiefly in the Lower Coal Measures, have been traced on the six-inch maps as far as possible. The Millstone Grits, also, have been examined in greater detail than was formerly attempted, and more character has been infused into the study of the series; this is rendered desirable by the fact that the correct interpretation of many areas involving Coal Measures depends on the intelligent reading of the Millstone Grit succession.

The upper portion of the Millstone Grit series is now well known, and a complete detailed succession of the Lower Coal Measures has been established.

The beds below the Kinderscout Grit form small inliers at Scout Spa on Walsden Edge and immediately west of Blackstone Edge; they appear to owe their presence to local periclinal uplifts.

The faulting of the area considerably complicates the structure. The most important system has a N.W.–S.E. trend and is broadly confined to two main belts. The more powerful one ranges from Readycon Dean in the south, passes west of

[1] E. Hull, 'The Geology of the Burnley Coalfield' (*Mem. Geol. Surv.*) 1875, pp. 9 and 100–101.

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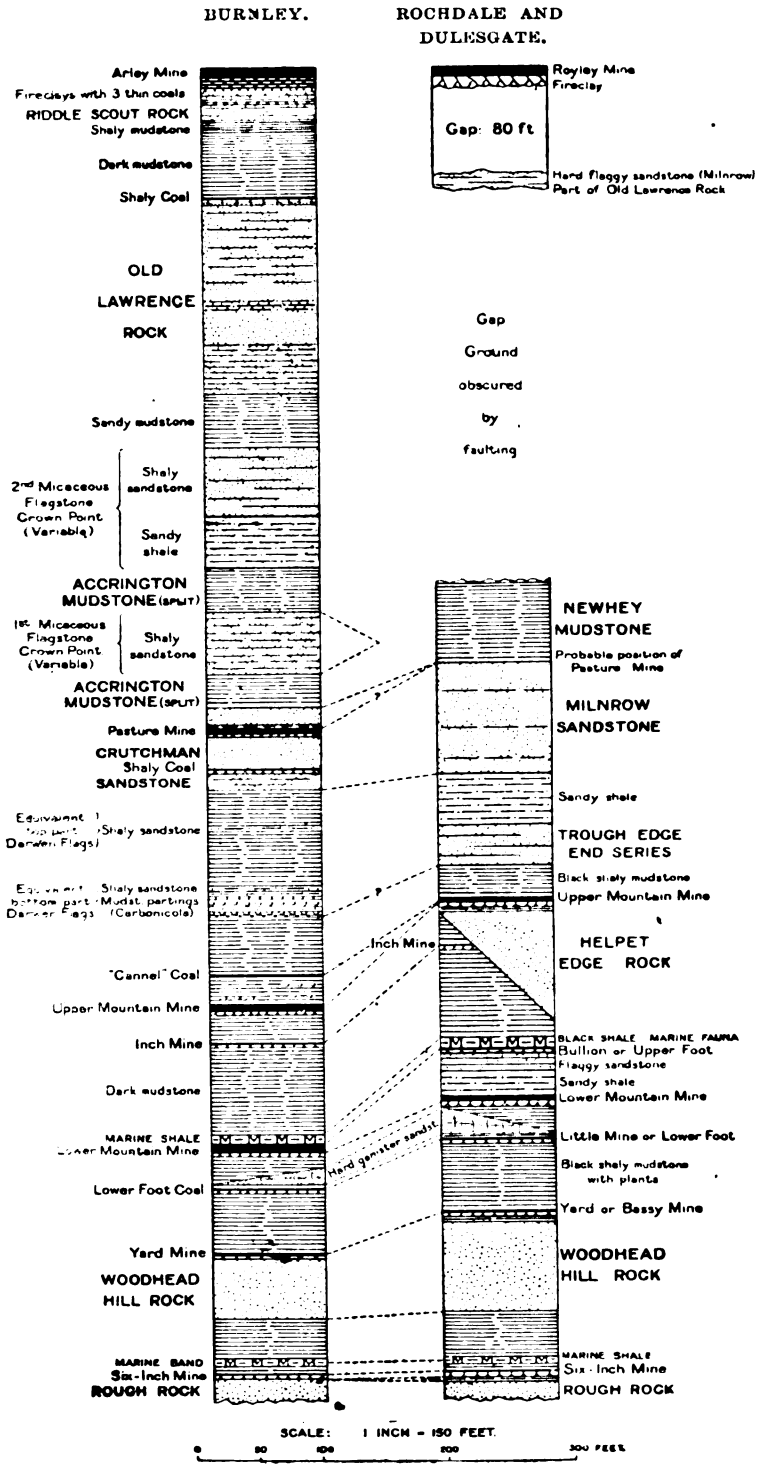

FIG. 2.—*Lower Coal Measures Succession in the Burnley and Rochdale Districts.*

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Todmorden, and reaches Burnley as the great Cliviger Valley Fault, with its zones of fracture on either side; the second belt of N.W. faults extends from Hollingworth Lake to Shawforth in the Whitworth valley and appears to continue in that direction. In the Rochdale area an important E.N.E.–W.S.W. system of faulting has been observed, the effect of which is seen in a complete repetition of the Lower Coal Measures between Wardle and Milnrow. South-east of Burnley, on the other hand, there are indications of this system having swung round to a E.S.E.–W.N.W. direction, an example of which is the Thieveley Lead Mine Fault.

In a few localities there are instances of a curved type of fault, trending east and west at the southern end and practically north and south at the northern end, the concave side facing east. A good example of this kind, between Turn Slack dam on Shore Moor, and the Longden End valley, has a large downthrow in the middle part of its course, but dies away rapidly in both directions. This type of fault is local rather than regional, and is probably related to the folding which preceded the fault systems previously mentioned.

Millstone Grits.—The original broad classification of the Millstone Grits has been found applicable in the area under consideration. Considerable doubt exists, however, regarding the former conception of the Third Grit series as comprising several beds of massive grit. The accompanying vertical section shows the position in relation to the Rough Rock of the bed at present referred to as 'The Third Grit'; its position relative to the Kinderscout is the subject of present enquiry and correlation. Nowhere has an unbroken section of the beds between the Kinderscout and the Third Grit been seen, but the mapping of the past season suggests a probable reduction in the thickness formerly assigned to these beds.[1]

In this connection the evidence afforded by marine bands is suggestive but at present inconclusive. A marine band containing a mutation of *Glyphioceras reticulatum* (Phill.) has been found lying above a coal which rests on flaggy grit a hundred feet above the Kinderscout in Dry Clough on Bleaked Gate Moor. In Rams Clough on Worsthorne Moor near Burnley a bed of flaggy grit overlain by a coal occurs about two hundred feet below the Third Grit. The shales immediately above this coal contain a marine band with *Glyphioceras reticulatum* (Phill.), which Mr. Bisat considers to be of the same sub-species as the one in Dry Clough. There is, therefore, a fair presumption that the two bands are identical, and, if examination of further material should lend support to this view, then it will be possible to reconstruct the succession from the higher grits right through to the Kinderscout.

More direct evidence bearing on the suggested reduction of the 'Third Grit Series' is to be found near Todmorden. The

[1] 'The Geology of the Burnley Coalfield' (*Mem. Geol. Surv.*), 1875 p. 40.

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massive, coarse (and sometimes conglomeratic) grit which makes bold crags on the S.W. side of the Cliviger gorge at Lydgate, was formerly mapped as a member of the Third Grit Series. The bed is now definitely considered to be Kinderscout Grit; it can be traced to the country south of Todmorden, where its stratigraphical relationships again place it as Kinderscout. Confirmatory evidence for this conclusion is supplied by the discovery of a marine band lying between two and three hundred feet below this grit and bearing a strong resemblance in its fauna to a band in Crimsworth Dene which occurs below proved Kinderscout.

At least six definite fossiliferous horizons have been established between the Kinderscout Grit and the Rough Rock; and while the recognition of these bands has proved of considerable help in the correlation of certain isolated exposures, the confirmation they afford to the lithological mapping alone emphasises their importance. The positions of these marine horizons in relation to the lithology are seen in the accompanying vertical sections of the Millstone Grits (Fig. 3).

The Holcombe Series[1] in this district shows remarkable development and variation. Fine natural sections of these beds, along with other members of the Millstone Grit Series, are to be seen in Greens Clough, Portsmouth; in Paul Clough and Swinden Water on the moors north of the Cliviger valley, and in Gorpley Clough and the Dulesgate valley near Todmorden. The Holcombe Series is everywhere in this area defined by a coal (the 'Holcombe' Coal) which lies at the base of the mudstones and shales underlying the lowest bed of Haslingden Flags; constant with this coal is also a marine band 20–30 feet above it, characterised by an undescribed species of *Gastrioceras* and a mutation of *Glyphioceras reticulatum* (Phill.), which are being dealt with by Mr. Bisat. Below this coal, however, considerable variation takes place, and widely different facies are observed at this horizon. Thus, at Ratten Clough Wood, near Portsmouth, the following section of the Holcombe Series is seen :—

Haslingden Flags. Lower Bed.	—
Mudstone and shale with marine band 30 feet from base	60 feet.
Coal (the 'Holcombe' Coal)	6 inches.
Fireclay	3–4 feet.
Variable dark sandstone and sandy mudstone	6–8 feet.
Coal smut	—
Fireclay and fireclay mudstone (average 12 feet good fireclay)	15 feet.
Coal smut	—
Fireclay, passing down into sandy fireclay mudstone	6 feet.
Strong fine siliceous sandstone; variable character	15 feet.

The fireclay between the two coal smuts is of good quality and has been mined extensively from adits driven into the hillside.

A mile to the north-east in Paul Clough, the Holcombe Coal rests on about 25 feet of sandstone and sandy shale with no trace of the lower coal smuts, which character is maintained in

[1] 'Summary of Progress for 1921.' (*Mem. Geol. Surv.*), 1922, p. 40.

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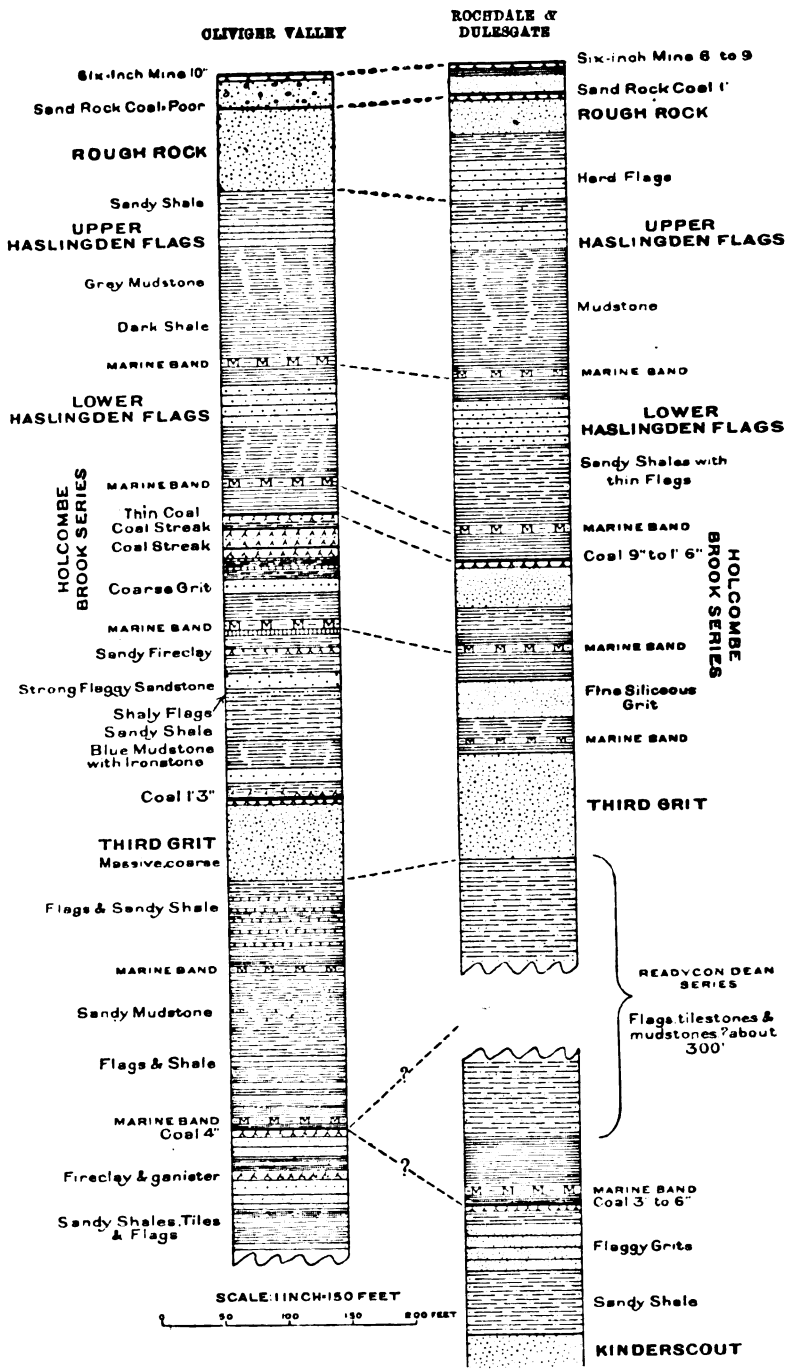

FIG. 3.—*Millstone Grit Succession in the Burnley and Rochdale Districts.*

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a northerly direction across the Worsthorne Moor to Swinden Water. The same replacement of the fireclay series by sandy material is observed as the beds are traced south from Ratten Clough Wood to Dulesgate, where a fairly massive grit, ganister-like at the top, immediately underlies the Holcombe Coal. Coincidently with this general development of sandy beds in a southerly direction, the sandstone at the base of the series in Ratten Clough Wood appears to be largely replaced in Greens Clough, Portsmouth, by grey mudstone.

Little further can be said at present concerning the relation to the succession now detailed, of the Millstone Grits mapped last year on the east side of the Pennine anticline. It would appear, however, that the beds then described as 'The Third Grit beds'[1] correspond in part to the Readycon Dean Series of the Rochdale district, and nowhere reach the horizon of the Third Grit.

Lower Coal Measures.—Between Burnley and Rochdale the Lower Coal Measures occur chiefly on the west (upthrow) side of the Cliviger Valley Fault. On the downthrow side of this great fault a complete succession of Lower Coal Measures crops out in the Cliviger valley between Redwater Clough and Riddle Scout; the tracing of individual beds, however, is here complicated by extensive land-slipping. From this point a belt of Lower Coal Measures extends almost due north across moorland country, where the 'mountain mines' have been little exploited owing to their inaccessibility and the high dip of the beds at their outcrop.

Between Todmorden and Rochdale the lower beds of the Lower Coal Measures are subjected to frequent repetitions by powerful north and south fractures. And as all the workable coals are confined to the lower beds, exploitation by outcrop and shallow workings is thus both facilitated and extended.

The higher beds of the Lower Coal Measures are concealed under a thick covering of drift around Rochdale, but are widely exposed over the country north of the Dulesgate valley. Especially good exposures occur on the moors and in the cloughs N.W. and S.E. of Thieveley Pike.

Outcrop and adit workings commenced at Easden Wood, Deerplay, during the coal strike of 1921 have been extended by the Deerplay Collieries, Ltd. The throw of the Thieveley Lead Mine fault[2] is here demonstrated very clearly, the Arley Mine, Lower and Upper Mountain mines outcropping in close proximity. All three coals are worked, and small additional areas in the Arley and Upper Mountain have been proved. The tipped material from the Lower Mountain Mine workings in Black Clough affords an excellent opportunity for examining the marine shales, bullions and coal balls associated with this horizon.

[1] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 43.

[2] 'The Geology of the Burnley Coalfield' (*Mem. Geol. Surv.*), 1875, p. 85. The throw of the fault probably does not exceed 900 feet.

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Only two marine horizons have been found. One, well known as the Bullion Bed, overlies the Bullion or Upper Foot Coal and has already been referred to.[1] It has been observed, though, that while the occurrence of bullions is sporadic, the black shales overlying the coal everywhere contain the marine fauna. It is to be noted also that bullions are by no means confined to this bed.

The other marine band occurs in the shales immediately overlying the Six-inch Mine, at the base of the series; the coal with its fireclay usually rests directly on the Rough Rock, but is occasionally separated from it by several feet of shale. This is the case on the south side of Dulesgate. The Six-inch Mine marine band contains *Pterinopecten*, *Posidoniella*, and goniatites, but the poor state of preservation renders specific determinations difficult.

A bed rich in *Lingula* (?), but containing no other shells, has been seen in several localities five feet above the Lower Foot or Little Mine; this, however, would appear to represent an estuarine rather than a marine incursion. Plant remains are common at many horizons, notably towards the base of the series.

A fairly uniform character throughout the area is observed in the lower beds up to the horizon of the Lower Foot Coal. The latter is usually separated from the Lower Mountain (or Ganister) Mine by 30 feet of black shale, but between Dulesgate and Greens Clough the shales are largely replaced by a hard white sandstone. Considerable change also takes place in the same area, between the Lower Mountain Mine and the Bullion Coal. North and west of Littleborough these coals are separated by 36 feet of sandstone and sandy shale, while at Clough Foot, in the Dulesgate valley, only 3 feet of shale intervene.

The two coals coalesce immediately north of Clough Foot, and throughout the district mapped to the north only one coal occurs at this horizon. The coals come together somewhat abruptly on Inchfield Moor; the intercalated sandstone is seen to die out rapidly in the Foulclough colliery workings and both seams crop out in close proximity on the northern slopes of Inchfield Moor. As a result of this union the marine band overlying the Bullion Coal becomes associated with the Lower Mountain Mine in the Burnley district.

Where the Lower Mountain Mine and the Bullion Coal are separated, the former is of good quality, but the Bullion Coal is often impregnated with pyrites. The following section[2] of the

---

[1] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 42. *N.B.*—This marine horizon overlies the Lower Mountain Mine in the north of the area.

[2] We are indebted to Mr. T. Walton, manager of Rowley Colliery, Burnley, for this and other information.

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Lower Mountain Mine at Bank Hall Colliery, Burnley, where the two coals are united, is thus of interest :—

Coal with irregular cannel streaks and iron pyrites which partly infiltrate the middle portion - - - - - - - - -	15–16 inches
Good coal, comparable with Lower Mountain Mine where latter is separated - -	18 inches
Pyritous coal with streaks of dirt - -	12–14 inches

The Helpet Edge Rock[1] underlying the Upper Mountain Mine in the Rochdale and Milnrow districts dies out in a northerly direction; around Burnley the Lower and Upper Mountain mines are separated entirely by mudstones in which the Inch Mine and fireclay occur about 25 feet below the Upper Mountain Mine. This mudstone facies, along with the Inch Mine, persists over the moors on the west side of the Cliviger valley, and for some distance south of Dulesgate. Occasionally, however, the fireclay seat of the Upper Mountain Mine rests on several feet of flaggy sandstone, which may be regarded as a feeble representative of the Helpet Edge Rock. The latter is also represented in the narrow belt of Lower Coal Measures north of Cornholme by a bed of hard fine flagstone which extends down almost to the Inch Mine.

The ' Cannel ' Coal, lying from 3 to 8 yards above the Upper Mountain Mine in the Burnley district, appears to be quite absent south of Heald Moor. It is very probable that a union of the two seams takes place. At Easden Wood and Black Clough on Deerplay Moor the coals are separated by 10 to 15 feet of fireclay and sandy mudstone, which, together with the Upper Mountain Mine, thin to the south, while the Cannel Coal is seen to thicken in the same direction in the workings of the Easden Wood Colliery; and when next seen in Greens Clough, still farther south, the beds contain but one coal at this horizon.

Between Rochdale and Dulesgate a persistent bed of flags lies about 30 feet above the Upper Mountain Mine. It is typically developed at Trough Edge End, where it has a thickness of 30 feet. North of Dulesgate the flags thin out along the west side of the Cliviger valley, and are represented by only a few feet of flaggy sandstone. On the opposite side of the valley, however, a 15-ft. bed of hard fine flagstone is seen in Cartridge Clough at this horizon, and increasing in thickness to the north, gives rise to the feature of Pike Hill on Worsthorne Moor. This bed of sandstone is the equivalent of the Darwen Flags of the country to the west.

The Pasture Mine is seen only in the northern half of the area, and even there its occurrence is inconstant. The sandstone (the ' Crutchman ') underlying the coal in the Bank Hall Colliery shaft increases in thickness and strength to the south; as a massive fairly coarse sandstone it makes a strong feature

[1] ' Summary of Progress for 1921 ' (*Mem. Geol. Surv.*), 1922, p. 42.

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over Todmorden Moor, where it is at least 60 feet thick, and is overlain by a fireclay varying in thickness from 1 to 6 feet, which is worked near Sharneyford.

Farther south, near Rochdale, the 'Crutchman' is represented by the 90 feet of hard flaggy sandstone quarried at Milnrow, but the Pasture Mine and fireclay are here apparently absent.

A thick fireclay horizon with coal streaks occurs at the horizon of the Pasture Mine in Cartridge Clough, north of Cornholme, and borings indicate the presence of the coal and fireclay under Worsthorne, several miles farther north. It is clear, however, from a comparison of these borings with the sections of the new reservoir at Hurstwood[1] that in less than a mile the Pasture Mine passes into black shale and the fireclay disappears. As the reservoir lies between Worsthorne and Cartridge Clough, the significance of the appellation 'The Gay Deceiver' already applied to this seam[2] is here well demonstrated.

The Accrington Mudstones form a characteristic horizon everywhere, overlying the 'Crutchman' sandstone, but their thickness varies considerably. When traced east from Accrington into the Burnley district, they are seen to take in flaggy beds, which reduce the workable thickness of the series for brick-making purposes. Farther south the mudstones (known as the New Hey Mudstones) are worked extensively for brickmaking around Rochdale, where a thickness of 60 feet has been proved; the top, however, is not seen, and over much of the ground they are buried under drift.

The Old Lawrence Rock, which succeeds the Accrington Mudstones, is sometimes mappable as two beds; this is the case at Easden Wood, on the northern part of Deerplay Moor, and in the Cliviger valley south-east of Riddle Scout. In the last named locality the intercalated mudstones resemble the Accrington Mudstones, but as a rule the weak partings, where they occur in the Old Lawrence Rock, consist of sandy shale.

In the north, the Old Lawrence Rock is typically developed east of Worsthorne, where owing to its low dip, it makes a great surface spread, and has been quarried in the past for building stone; its outcrop is terminated on the west by a fault which ranges N.W. through Worsthorne village and throws down Middle Coal Measures on the west.

A constant feature in the upper part of the Lower Coal Measures is the 50 feet of shale and mudstone which intervenes between the top of the Old Lawrence Rock and the base of the Middle Coal Measures. The Riddle Scout Rock, a bed of sandstone similar to the Old Lawrence in character, everywhere separates these mudstones from the seat earths and thin coals

[1] Acknowledgment is made to Messrs. Mackenzie & Baldwin for readily given help and information.

[2] A. J. Tonge, 'Sinking into the Lower Coal Measures at Hulton Colliery,' *Trans. Man. Geol. Soc.*, 1910, vol. xxxi, p. 256.

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below the Arley Mine. It has nowhere been seen to exceed a thickness of 20 feet, and often contains shaly partings.

These higher beds of the Lower Coal Measures, as has been mentioned previously, are mostly obscured by drift where they occur in the Rochdale district. The exposure of massive sandstone at Belfield Mill in the Beal valley, appears to be the local representative of the Old Lawrence Rock.

Middle Coal Measures.—The Middle Coal Measures occupy the relatively low, drift covered ground, and good natural sections are therefore rare. The succession of the lower beds is well seen, however, on the north-east side of the Cliviger valley between Riddle Scout and the Lowe; the Arley, Dandy, and China coals being each associated with a prominent escarpment. Numerous records of borings and pit sinkings have provided valuable material for supplementing field observations in the drawing up of a complete succession from the Arley (or Royley) Mine at the base, to the Dog-Hole Coal, representing 1,030 feet of strata. The chief coals are shown in the accompanying vertical section.

In the Rochdale district the Middle Coal Measures are contained in an area of less than one-sixth of a square mile. A little over 300 feet of measures have been proved above the Royley Mine, and comparison with the Burnley succession reveals considerable lateral variation. The Bottom Neddy or Smith Coal appears to be the equivalent of the Dandy Mine of Burnley, in which case the Bone Coal would represent the Crackers Mine.

Glacial Drift.—Loamy gravel, with interbedded red sand (the latter dug for industrial purposes) is the predominant type of drift in Rochdale district; most of it appears to be of morainic origin. Boulder-clay, chiefly of the Ribblesdale type[1] is prominent around Burnley, particularly on the east side, where it ascends to over a thousand feet above sea level.

The progressive stages of retreat of the ice are indicated by numerous overflow channels; the series north of Littleborough appear to have discharged their waters into the Summit gorge, which probably marks the final overflow. At this stage the Calder valley received the waters from the Summit gorge and also the overflow from the Burnley district *via* the Cliviger gorge. The several overflow channels notching the ridge on the north side of the Cliviger gorge mark the escape of the water impounded in the Sheddon and Thursden valleys, at the time when the natural outlets of the latter were blocked by the ice sheet.

The area surveyed by Mr. Tonks embraces the town of Burnley and the district of Habergham Eaves. The Lower Coal Measures are well exposed in many natural sections notably in New Barn Clough and in Habergham Clough and its tributaries. The succession is everywhere the normal one

[1] A. Jowett, 'Glacial Geology East of Lancashire,' *Quart. Journ. Geol. Soc.*, vol. lxx, 1914.

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given on p. 47, except in one or two cases. In New Barn Clough, for instance, the Upper Mountain Mine is underlain by about 8 feet of flaggy sandstone and sandy shale. These beds are the local equivalents of the Helpet Edge Rock of the Rochdale district. Again, the Pasture Mine is exposed near Wholaw Nook and in Copy Clough in its normal development, but towards the south-east it dies out. A shaft was sunk from the Arley Mine to the Lower Foot at Bank Hall Colliery just before the war. Specimens of this valuable section have been preserved, and have been examined by permission of the proprietors of the colliery[1]. The accompanying vertical section (Fig. 2, Burnley District) is based on this record. At Bank Hall the Upper Mountain Mine is being got below the old workings in the Arley.

Middle Coal Measures.—The Middle Coal Measures lie in the trough of the Burnley syncline. South and south-west of Burnley the southerly limb of this syncline gives rise to a country dip of 10°–12° to the north-north-west. Northwards the dip changes in direction. West of Burnley it is 8° to E.N.E.; and east of the town it is 6° to W.S.W. The structure, therefore, is that of an elliptical basin with its long axis trending approximately W.S.W.–E.N.E.

The basin is broken by many faults. The big faults are remarkably constant in direction, and run N.N.W.–S.S.E. Smaller faults, running approximately east and west, cross between the main lines of faulting. The north-westerly faults are not simple fractures, but are, as a general rule, narrow and complicated fault belts. One big fault is frequently accompanied by a series of smaller compensating faults, which throw in the reverse direction to the major fault of the belt. Other fault belts attain their total throw by a series of small steps, all throwing in the same direction. The net throw of each main fault belt, west of Burnley, is down to the north-east. The amount of throw is variable and inconstant. Big faults with a throw of several hundred feet frequently fork and die out in a few hundred yards.

The Middle Coal Measures are not well exposed in this district, as they lie in the low ground where the drift is thick. Many shaft sections are, however, available to supplement the information obtained from natural sections, and the general succession of the principal coal-seams is shown on the accompanying vertical section (Fig. 4).

A remarkable instance of lateral variation, accompanied by the displacement of at least two coal-seams, has been observed in this district. Fifteen yards below the Low Bottom Coal, the Inferior Cannel Coal rests on a thick sandstone. This sandstone is exposed in the Whitegate and Lumb Wood Quarries, Habergham; and in Sweet Clough, just north of Lowerhouse Mill. It is a

[1] The executors of John Hargreaves, Ltd. We are greatly indebted to the Managing Director of this firm, Mr. Richard Landless, for many valuable sections, plans and records of mines in the Burnley district.

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fine-grained grey and brown sandstone with some mica, false-bedded, and concretionary and ferruginous in parts. Towards the base it becomes coarser. It occurs in massive lenticular beds

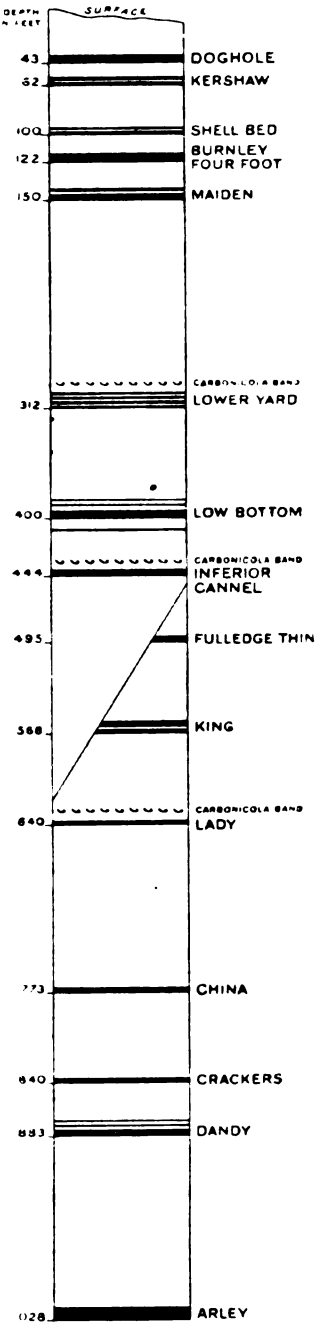

FIG. 4.—*Section showing the sequence of the chief coal seams of the Middle Coal Measures, Burnley District.* (*Depths in feet.*)

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with irregular partings of sandy shale, which is crushed and thrust between the massive lenticles. This sandstone was 121 feet thick in the Habergham Pit Shaft, and 132 feet in the Clifton Colliery Shaft. The King Mine and the Fulledge Thin Mine (*see* Vertical Section, Fig. 4) were absent in both these sections. In the Bank Hall Colliery Shaft the sandstone was 103 feet thick, and rested on the King Mine. When the King Mine was being worked at Bank Hall it was found that the sandstone roof descended and cut out the coal about 500 yards north of the colliery. The sandstone was formerly exposed in the old Pickup quarry, south of the Infantry Barracks. Here it rested on the King Mine. The increase in thickness takes place in a northerly direction; and the base cuts transgressively across the underlying measures. It is considered that the transgression is part of a great 'wash-out'[1] in the Middle Coal Measures.

The thick coal-seams above the Low Bottom Coal were formerly exposed and worked in the centre of the synclinal basin under Burnley. They are now exhausted, and no new evidence has been obtained as to their position or character.

Glacial.—A thick drift mantle covers the low-lying ground on which Burnley stands. This cover thins southward on the lower slopes of Hapton Park, and on the top of Hameldon Hill only scattered erratics occur. About 3 feet of laminated clay is seen west of Lumb Wood quarry and appears to be thinning westwards. It rests on stiff grey till with limestone boulders ('Ribblesdale Drift' of Jowett). A similar wedge of laminated clay occurs on the side of Hapton Clough near Old Barn Farm. Beds of laminated clay are reported as being frequently exposed in digging for drains, etc., under the town of Burnley. Glacial striæ, running due S.E., have been found on sandstone at Habergham Quarry.

4. Cumberland District

Headquarters: Whitehaven

Bernard Smith, M.A., District Geologist.
E. E. L. Dixon, A.R.C.Sc., B.Sc. } Senior
T. Eastwood, A.R.C.Sc. } Geologists.
F. M. Trotter, B.Sc.
S. E. Hollingworth, B.A., B.Sc. } Geologists.
L. H. Tonks, M.Sc.

Mapping in the Carlisle area was actively advanced by Messrs. Dixon, Trotter, Hollingworth and Tonks. Some time was spent by the senior geologists in training the younger members of the staff.

[1] Compare, for example, the Parkgate 'wash-out' in Yorkshire, described by Prof. P. F. Kendall—Presidential Address, Section C, British Association Meeting, Hull, 1922.

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In the Whitehaven district the year's work was chiefly undertaken by Messrs. Smith and Eastwood. Recent borings south of Egremont were examined by Mr. Smith.

Carlisle, Longtown and Silloth District

The mapping of the New Series Sheet 17 (Carlisle) has been completed and the smaller Sheets 16 (Silloth) and 11 (Longtown) have been resurveyed. Sheet 18 (Brampton) has been commenced.

CARBONIFEROUS

Mr. Trotter has mapped a limited spread of the Scottish Carboniferous Limestone Series lying in Sheet 12 (Shopford), east of Sheet 11. The rocks are purple and grey sandstones and purple and chocolate shales with minor beds of limestone, cementstone and conglomerate. The sandstones are fairly easily distinguishable from the St. Bees Sandstone but more difficulty is experienced in distinguishing between the chocolate Carboniferous shales and the St. Bees Shales. Similar beds are recorded from a borehole at Riddings (p. 61).

NEW RED SERIES

In the Carlisle district some exposures have been found by Mr. Dixon in the upper part of the Trias that throw light upon the much-debated question of the local sequence of these rocks.

Three different interpretations of the sequence in the district have been advanced :—

T. V. Holmes.	*Prof. Gregory.*	*Present Grouping.*
Lower Lias.	Lower Lias.	Lower Lias.
Stanwix Shales.	Stanwix Shales.	Stanwix Shales. (of Abbey Town boring).
Kirklinton Sandstone.	Kirklinton Sandstone.	Kirklinton Sandstone.
Upper Gypseous Shales. (of Abbey Town boring).		
St. Bees Sandstone.	St. Bees Sandstone.	St. Bees Sandstone.
Lower Gypseous Shales.	Gypseous Shales. (of Abbey Town boring).	Lower Gypseous Shales.
Penrith Sandstone.	Penrith Sandstone.	Penrith Sandstone.

Holmes' sequence, the evidence for which has been stated clearly and in detail in several publications,[1] may be said to be that most generally accepted. As, however, the distribution of the beds referred by him to the Upper Gypseous Shales postulates an unconformity between the Lower Lias and the Trias of a magnitude unknown elsewhere in the country, his views have not been adopted on the map published by the Geological Survey, which omits the 'Upper Gypseous Shales,' and shows the St. Bees Sandstone as followed by the Kirklinton Sandstone directly, and the Stanwix Shales as underlying the Drift of Abbey Town.

[1] 'The Permian, Triassic and Liassic Rocks of the Carlisle Basin,' *Quart. Journ. Geol. Soc.*, vol. xxxvii, 1881, pp. 286–98; 'The Geology of the Country around Carlisle' (*Mem. Geol. Surv.*), 1899; and 'On the Evidence as to the Geological Structure of Cumberland bordering the Solway,' *Geol. Mag.*, 1915, pp. 410–18.

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This accords with what has been learnt during the recent revision.

In the country north of Carlisle Mr. Trotter finds no evidence that calls for an unconformity between the St. Bees and Kirklinton Sandstones.[1] Again the 'Kirklinton' upper part is overlain by the Stanwix Shales, but to the south-west the latter formation had not been identified, and Holmes has concluded that in this direction it is overstepped by the Lias; for at the Abbey Town boring, he found that the formation beneath the Drift, though consisting of red and variegated shales like those of Stanwix, carried much gypsum, and that the underlying sandstone, at a depth of only 43 feet beneath the shales, resembled St. Bees Sandstone.

It has now been found by Mr. Dixon that along the River Caldew, south-west of Carlisle, the Stanwix Shales are present in normal sequence between the Kirklinton Sandstone and the Lias, and extend right across the area shown as Kirklinton Sandstone on the map that illustrates Holmes' view.[2] The Stanwix Shales rest upon both brightly-coloured and pale grey beds of Kirklinton type, and apparently dip northwards beneath the Liassic plateau, under which red shales with gypsum were found near Great Orton in a boring made in 1781. These newly discovered field-relations dispose to a great extent of the difficulty of correlating the gypsiferous shales of Abbey Town with the Stanwix Shales of Carlisle.

The difficulties introduced by Prof. Gregory's correlation, although he points out various obstacles in the way of accepting Holmes' theory, are even greater than those it was designed to overcome. Arguments in favour of the view now accepted and against the views of other writers will be discussed in the forthcoming memoir.

In the ground examined by Mr. Hollingworth, in the neighbourhood of Thursby and Aikton, Glacial Drift conceals the outcrop of the Triassic rocks, but an interrupted section of the Gypsiferous Shales and Marls and the overlying St. Bees Sandstone was found extending for three-quarters of a mile along the Boston Beck and its upward continuation, Jacobs Gill, dipping at about 10° downstream. The dip of the St. Bees Sandstone, in which marly beds are rare, averages 15° to the N.N.W. The drift-covered depression between this exposure and the Liassic plateau allows for a considerable breadth of outcrop of the higher divisions of the Trias.

On the northern flank of the Carlisle Basin, Mr. Trotter finds representatives of the Kirklinton and St. Bees Sandstones and underlying gypsiferous marls forming a syncline with an axial trend from S.S.W. to N.N.E. The base of the series is exposed in Carwinley Burn (Sheet 12), 600 yards east of the Longtown-

[1] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 45.

[2] *Quart. Journ. Geol. Soc.*, vol. xxxvii, 1881, pl. xi; *Geol. Mag.*, 1915, pl. xiv.

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Penton road as 6 feet of coarse breccia dipping to the W.S.W. at 10°, overlying purple Carboniferous shales and coarse flaggy sandstone dipping N.N.E. at 50°.

A borehole at Riddings appears to have passed through 8 ft. 6 in. of surface clay into 97 ft. 9 in. of the marl series, with numerous hitherto unsuspected beds of gypsum and three layers of conglomerate (breccia). The lowest breccia, 1 ft. 3 in. in thickness, may represent the local base of the Trias. The lower part of the bore proved 363 ft. 9 in. of sandstones and marls of Carboniferous age.

It is estimated that the marls are at least 200 feet in thickness; they pass gradually into the St. Bees Sandstone, being replaced upwards by beds of chocolate shale in ever diminishing thicknesses, between thickening beds of sandstone.

A continuous section of St. Bees Sandstone, conformably succeeded by Kirklinton Sandstone, occurs in Carwinley Burn to the S.W. of the outcrop of gypsiferous marl.

In the west bank of the Esk, at Kirkandrews, and in the east bank for a distance of 600 yards S.W. of the Carwinley Burn, there are good sections of bright-red Kirklinton Sandstone—in the latter case very near the base of the group. The exposure of Kirklinton Sandstone at the lower end of Carwinley Burn covers a considerable extent of ground owing to the synclinal structure. Its thickness here is not more than 100 feet.

LIAS

No evidence has been obtained regarding the presence of Rhaetic beds beneath the Liassic plateau west of Carlisle. The Lias is exposed in two small stream sections, the one at Flat, south of Thurstonfield, the other near Thornby (S.E. of Aikton). Fossils have been collected at both localities. The other records are from wells in the Orton and Wiggonby districts; the well at Great Orton passed through Lias and ?Rhaetic into red shales with gypsum at 228 feet depth.

GLACIAL

The Carlisle area was invaded by a sheet of ice that radiated from the mountainous district around Criffel in the south of Scotland. The deposits have been found to be due to two advances of the ice and two withdrawals, resulting in a lower and upper boulder-clay separated by middle sands and gravels, and a series of later sands and gravels formed during the final withdrawal. During the latter period glacier-lakes were held up on the low ground between the ice-front and the higher ground to the north, east and south.

Messrs. Dixon and Hollingworth have discovered evidence of glacier-lakes to the south-west of Carlisle, associated with eskers, deltas and overflows that lie chiefly in the areas mapped by Messrs. Maden and Hollingworth.

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Mr. Hollingworth reports that the Lias plateau is thinly covered by drift with poorly developed drumlins, whilst to the south the lower ground is more thickly covered and drumlin topography is well developed. The Lower Clay is a stiff plastic clay which becomes sandy at some points where a considerable amount of Triassic sandstone has been incorporated. A continuous bed of Middle Sands 15–20 ft. in thickness was traced over an area of 3 square miles in the southern part of his district.

It is probable that the Upper Boulder Clay is spread over nearly the whole of the area mapped by Mr. Hollingworth. At some points it is exceptionally sandy.

Two groups of boulders were recognised : Lake District types, and local and Scottish or ' Irish Sea ' types. The Lake District stones have, with rare exceptions, been found only south of the Lias plateau and have not been seen in the boulder-clays, whilst the Scottish types are common in both clays In the boulder-clay Triassic boulders are rare; they occur commonly in the upper glacial gravels by direct derivation from the solid. Mr. Hollingworth studied a group of three important lobed eskers in the low ground west of Thursby[1], running slightly north of west approximately parallel to the drumlins. The westerly trend is broken at intervals by sharp turns to the north, followed by a return to the original direction. These diversions appear to be across the drumlin ridges.

Deltas have been found at the mouths of a number of well-marked overflow channels at varying heights.

Mr. Tonks finds that the area inland of the Marine Alluvium is covered by boulder-clay in the form of long cigar-shaped ridges with steep-nosed fronts to the east and more gentle slopes to the west. Their alignment changes from N.E. near Old Mawbray to E. 23° N. at Highlaws and E. 10° N. at Waverbridge, indicating that the Scottish ice, travelling from a south-westerly direction, turned 35° eastward in a distance of 10 miles.

The only recognisable indicator-boulders are the Galloway granites. No Lake District boulders were found and no Middle Sands were observed. As in the ground surveyed by Mr. Dixon, the drumlins often have a steeper slope and shelf at various levels, *e.g.*, 50, 75 and 100 feet above O.D., apparently indicating the former existence of glacial lakes.

In addition to smaller patches a spread of Upper Sand and Gravel, covering nearly 4 square miles, south-west of Highlaws, was mapped by Mr. Tonks. Its elevation is from 145 to 150 feet above O.D., and it is concluded that it represents a deltaic mass formed in a lake, the overflow from which will be sought in the ground to the south.

Mr. Trotter finds the same quadruple arrangement of glacial deposits in the Longtown district. Middle Sands occur as high as 280 feet above sea-level. The Upper Sands are represented, in the neighbourhood of the Sark, by two spreads of sand and

[1] T. V. Holmes, ' Eskers and Kammes,' *Geol. Mag.*, 1883.

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gravel of deltaic origin; the southern at 100 feet, the northern at 140 feet above O.D.

Three persistent notches have been traced over the area at 200, 140 and 100 feet, and probably are the strand-lines of glacial lakes in which deltas were deposited at various localities.

POST-GLACIAL AND RECENT

Raised Beach.—The raised beach has been traced from a point a little south of Beckfoot to its termination at Grune Point, north of Silloth. The height of the beach, relative to high-water mark, decreases from Beckfoot to Grune Point; near Beckfoot it rests on the 3rd marine terrace; at Silloth on boulder clay, and at Grune on the 1st marine terrace. The beach has been formed by the addition of successive shingle ridges transverse to its length; its association with marine warps, indicates that, since the close of the Glacial period, the 'hook' has been travelling north-westwards, and that, as it has grown, the marine warps have accumulated in its front and lee.

Marine Alluvium.—The highest (3rd) terrace occupies a flat, three to four miles wide, which stretches from the coast to the boulder clay hills in the south and south-east, whilst the 1st and 2nd terraces are confined to Skinburness Marsh.

Submerged Forest.—Mr. Tonks reports the discovery of a Submerged Forest Bed at two hitherto undescribed localities.

A reef of dark and grey clay[1] emerges from a bank of sand, 1,250 yards S.S.W. of the bridge at Beckfoot and abuts seaward on the 'scar' known as Stinking Crag. The reef is 5 feet wide and lies 11 feet below high-water mark. During the summer of 1922 it was exposed for a distance of 120 yards, the section being as follows :—

Dark peaty soil, containing fragments of bark and leaves, with prone trunks and stools of trees ...	2 in.
Light grey clay (typical seat earth) with stones split by roots	6–12 in.
Stiff red boulder-clay with rootlets in upper part.	

Again on the southern edge of a boulder-clay 'scar' about half a mile north of Starry Hill, Skinburness, the following section was seen after high spring tides in September, 1922 :—

Dark peaty soil with five stools of trees	6 in.
Grey clay with splintered stones (base not seen) ...	6 in.

The submerged forest on Cardurnock Flats[2], was not visible during the present survey. Previous writers have ascribed this forest-bed to recent submergence; the magnitude however (over 11 feet) of the elevation necessary to raise it above the present

[1] Previously noted, but not described. *See* 'Report of the Royal Commission on Coast Erosion,' vol. i, 1907, pt. ii, p. 316a.

[2] T. V. Holmes, 'Notes on the Submerged Forest off Cardurnock on the Solway,' *Trans. Cumb. Assoc.*, pt. vi, p. 121.

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high-water mark, coupled with the fact that the raised beach has been continuously forming up to recent years, suggest that the period of destruction of the forest was anterior to the formation of the raised beach.

Workington, Whitehaven and Egremont District

The remapping of the Old Series Sheet 101 S.W. (New Series 28, Whitehaven) has been continued and much mining information has been obtained during the year.

SKIDDAW SLATES

A tract of Skiddaw Slates to the east of Cleator Moor was surveyed by Mr. Hollingworth who reports that on Flat Fell, Kinniside Cop and Dent, the rocks consist of alternations of thin buff and bluish-grey to black bands. The whole series appears to be sharply folded along axes pitching S.W. The least affected occur in the Merebeck as bluish-grey shaly and massive argillaceous beds. Mildly cleaved slates appear on the eastern portion of the ground mapped.

A number of dykes with a general N.W. trend have been discovered in the slates; some appear to be similar to those noted last year by Mr. Smith. In the neighbourhood of Nannycatch Gate a greater variety of dyke intrusions, ranging from light felspathic to dark basic types, is seen.

CARBONIFEROUS LIMESTONE SERIES

In the 'Summary of Progress for 1921,' the provisional grouping of the Carboniferous strata above the 1st Limestone, included the beds up to the Udale Coal as Millstone Grit, the rest being Coal Measures[1]. This was a purely lithological classification. Although the question is not definitely settled, sufficient palæontological evidence is now available to indicate that the bulk of these measures must be relegated to the upper part of the Carboniferous Limestone Series. The grit overlying the 1st Limestone—well developed at Overend quarry, Hensingham—will be referred to in future as the 'Hensingham Grit.' It has a thickness, as proved in two old borings in the neighbourhood, of 50 feet, while the beds above measure about 100 feet. Mr. Eastwood finds that the grit is succeeded by dark shales with thin and somewhat lenticular beds of limestone. These vary from dark earthy and sandy types to pale shaly and crinoidal, and yield a fauna determined by Mr. Pringle as being of D 3 horizon. Hence they are now placed in the Carboniferous Limestone. From the locality at Hensingham, where these limestone shale beds are admirably exposed, they are given the name of 'Snebro Gill Beds.'

The exposures of grit overlying the 1st Limestone in the area mapped by Mr. Smith about Bigrigg, farther south, with overlying

[1] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 55.

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shales nearly up to the horizon of the black goniatite shales (which are definitely recognised as of Millstone Grit age) are now also relegated to the Carboniferous Limestone Series on palæontological evidence.

Mr. Eastwood reports that the Lower Carboniferous Rocks in the Distington area are brought to the surface by a dome fractured on the south-west by a large fault introducing the lower part of the Coal Measures and accompanied by minor faults roughly parallel to the major dislocation.

Carboniferous Limestone is well seen in the old Barfs quarries. Most of the rock exposed is 1st Limestone, but on the western side of the largest quarry, dark shales resting on what is probably the 2nd Limestone are introduced by faulting.

The coarse Hensingham Sandstone and Grit, overlying the 1st Limestone, appears on the west side of Barfs main quarry, behind the lime kilns, and again on the north-eastern side of an older quarry to the south-west. Farther north, the quarries of Barfs Silica Works, furnish excellent sections, though the relation of the grit to the underlying limestone has not been determined. The grit varies from medium to coarse and contains a fair amount of decomposed felspar and some white mica. The dip is to the north-east at 10°. Recent 'baring' operations have revealed an excellent glaciated surface with striae ranging N.N.E. and S.S.W. In a cutting from the quarries the grit is truncated to the south-west by a downthrow south-west introducing newer beds, consisting of dark shales, sandstone and ganister, together with the remnants of a coal seam and some calcareous mudstones and earthy limestones that yield a fauna similar to that of the Snebro Gill Beds. A ganister forming the upper part of the group apparently behaves normally outside the disturbed area and dips south-westward at a comparatively low angle.

In the Cleator Moor—Bigrigg—Gillfoot area the main limestones have been examined and mapped by Mr. Smith at numerous points, the average direction of dip being a little south of west. The 7th Limestone is exposed at the old Todholes quarries, near Cleator Moor, but no exposure of the 6th Limestone has been noted. A collection of fossils was made from the 5th in a railway-cutting between Longlands Mine and Clints quarries in which there is also a splendid exposure of the whole of the 4th Limestone. Here the divisions[1] recognised by C. Edmonds were examined in detail.

The 3rd Limestone forms a small scarp above the top of the quarry. Good examples of contemporaneous wash-outs in the White Limestones, filled with mottled shales, have been exposed recently. A fault trending north-north-westward, with a downthrow west of about 35 ft., traverses the quarry and breaks the western face about the centre of its extent. To the west of the quarry the Ingwell-Bigrigg Fault[2] repeats the higher

[1] *Geol. Mag.*, 1922, p. 74.

[2] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 54.

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part of the 4th Limestone; the Saccammina Limestone and shale and the overlying Junceum beds appear in old quarries east of the road from Bigrigg to Egremont.

Farther west the Orebank Sandstone and overlying beds up to the 1st Limestone are exposed near the old Lady and Wyndham pits of the Bigrigg Mines. To the south they are cut off by an east-and-west fault at the north end of Clintsbrow Wood. This fault throws northward and swings the outcrop of the Junceum beds westward to the west side of the Bigrigg—Egremont road.

In Langhorn Quarry some sandstone dykes, with a maximum thickness of about 4 inches, were discovered in long strike-joints in the 1st Limestone. These infillings descend at least as far as the Little Whirlstone and indicate that the 1st Limestone was consolidated sufficiently to be jointed before the deposition of the overlying Hensingham Grit. The infilling appears to differ slightly from the Grit.

The 1st Limestone occurs beneath the Breccia in the railway-cutting to the New Clints Pit.

South of the Langhorn quarry exposures of the different parts of the 4th Limestone occur in a highly faulted area. Most of the faults proved by mining have been detected at the surface where the beds are free from drift.

Southward, in the direction of Orgill and Egremont, the New Red Breccia rapidly cuts out the higher limestones, and rests upon different parts of the 4th Limestone.

MILLSTONE GRIT

Mr. Eastwood reports that the dark shales associated with a thin coal, believed to be the Udale Coal, exposed in Bedlam Gill, Hensingham, and overlying the beds of Snebro Gill, yield marine shells. Of these, goniatites are characteristic and indicate, according to Mr. Pringle, that the beds are of Millstone Grit age. Over the Whitehaven–Workington area, exposures are extremely rare, and strata below the Four Foot Coal down to and below the Udale horizon are seldom penetrated in shafts and borings. Nothing is known of the fossils apart from those of the beds just mentioned, while such evidence as exists in this area points to the absence of any marked development of grit or sandstone between those seams, the rest of the sediments being of Coal Measures type; so that even if the Udale Coal is taken as the base, the top of the Millstone Grit Series still remains in doubt.

COAL MEASURES

The mapping of the Coal Measures by Mr. Eastwood has been continued northwards to Workington. The area is thickly drift-covered and apart from occasional sections between Winscales and Workington, little is seen of the formation except in the coastal region south of Harrington. Below that place and Parton the beach, cliffs and coast ravines afford good sections. About midway between the two places the Micklam Fault reaches

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the coast. South of that fault measures from about the horizon of the Cleator Six Foot seam down to near the Main Band are seen. North of the fault strata from the Six Quarters Coal almost down to the Four Foot Coal are well exposed, though dislocated by faults. Of these rocks, nearly 200 feet in thickness, the upper half consists mainly of shales and mudstones—sandstones as a rule being thin or of bastard type. In addition to chance coals, two thin but persistent seams of coal occur here. The upper is overlain by several feet of grey-black shales containing scattered *Carbonicola* and brown-skinned ironstone cakes; it is separated from the lower coal mainly by light bluish-grey mudstones. The lower coal has a seat-earth of fair grade fireclay and is accompanied, some feet below, by black shales with a 'mussel band' associated with a bastard ironstone-fireclay rock in which cone-in-cone structure is well developed. The rocks are best seen in Andrews Gill and in the cliffs and beach from the south of Cat Gill to beyond Fox Pit Gill.

The lower half of these measures contains more arenaceous material and is separated by dark shales into two subdivisions both of which exhibit a development of ganister towards the top. On the beach the ganisters weather into rough surfaces upon which casts of *Stigmaria* are not uncommon. The sandstones of this group vary from fine to exceedingly coarse in the space of a few feet, both laterally and vertically, this being especially the case with the lowest one exposed on the beach west of Andrews Gill. Here the rock contains patches including fragments of quartz up to an inch in length, although adjoining portions contain lenticles of coal and pass into fine ganister. Little has been seen of the middle portion of the Productive Coal Measures, though they occur below the drift in the Workington area. In this neighbourhood mining has been long abandoned.

The Whitehaven Sandstone Series occupies the trough between two faults skirting the park of Gilgarron House, and is believed to come on again north of the Wythemoor Fault on Winscales. In this area arenaceous types only have been found and there is no reason to suspect the presence of higher beds containing Spirorbis limestone.

NEW RED SERIES

The basement breccia of the New Red Series is visible at several points in the Bigrigg-Gillfoot area. It overlies 1st Limestone in quarries near Orebank House, and in the railway-cutting to New Clints Mine, where it oversteps the limestone. It overlies the Hensingham Grit east of Orebank House and also in an old quarry immediately to the north. It caps the grit also in the neighbourhood of Croft Pit (Bigrigg Mines) and has been proved in many borings to the south and west, being shifted to and fro by the ore-bearing faults.

The most southern exposure occurs W.N.W. of Gillfoot House In this neighbourhood the breccia passes upwards into the St

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Bees Sandstone through red sandy marls with occasional breccias and veins of gypsum.

Specimens of breccia collected near Orebank House give evidence that the mineralization of limestone to hæmatite followed the deposition of the breccia. The chief facts are that the matrix of the breccia, enclosing larger isolated fragments of ore, has been itself converted to 'blue' ore; that the alteration occurs most commonly close to post-Breccia faults, and in breccia containing a high proportion of derived limestone fragments.

The St. Bees Sandstone is of normal type, with beds of chocolate shale at intervals. It is actively quarried at Bank End, west of the Bigrigg Mines.

In the Calder Bridge area, south of Egremont, the higher sandstones (probably equivalent to the Kirklinton Sandstone) contain a thick horizon in which æolian sand grains predominate.

GLACIAL

In the area examined by Mr. Eastwood the solid geology is almost completely masked by drift. Upon the east this is mainly boulder-clay, but on the west, from Harrington northwards, the clay is overlain by sand and gravel apparently of deltaic origin.

Mr. Hollingworth finds that the Ehen valley, apparently pre-glacial, was filled with alternations of cemented gravel, sand and red and chocolate clays, frequently laminated, through which the present stream now runs. The boulder-clay is of the red sandy Irish Sea type with Whitehaven and St. Bees Sandstone pebbles. The Nannycatch valley at the head of the Udale valley appears to have drained glacial Lake Ennerdale[1] at just below 700 feet and was joined at a later stage by a channel round the north-east of Flat Fell cut by waters from a lake at a little above 600 feet. A lower lake may have had an exit down the Nannycatch valley at Nannycatch Gate.

Mr. Smith finds that the stiff boulder-clay of the Cleator Moor and Bigrigg district becomes more sandy as it is followed south-westward over the sandstones. Here and there it contains patches of stiffer clay, probably dragged over the escarpment in the lower layers of the ice. A large part of the area, although free from true boulder-clay, has a sandy soil full of erratics.

A spread of Upper Boulder Clay, of which the first indications were found last year,[2] has been discovered south of St. Bees overlying the Middle Glacial Sands and Gravels. It is confined to a shelf between the cliff and the feature formed by the St. Bees Sandstone, and attains a maximum thickness of about 30 feet. It was considerably dissected during the second retreat of the ice—Deepgill Banks is a good example of a marginal drainage channel cut at this stage. Some sands and gravels, with a general E. to W. alignment, upon the higher ground to the east were probably

[1] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, Appendix I, p. 124.

[2] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 68.

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formed in the early stages of the final retreat of the ice. Boulders of Carrock Fell gabbro and other well known Lake District rocks have been found on the beach and inland south of St. Bees. A series of fluvio-glacial sands and gravels has been mapped near Egremont.

5. Northumberland and Durham District
Headquarters : Newcastle-on-Tyne

R. G. Carruthers, District Geologist.
C. H. Dinham, B.A., Senior Geologist.
G. A. Burnett, B.Sc., A. Fowler, B.Sc., J. Maden, M.Sc., W. Anderson, B.Sc., } Geologists.

During the past season good progress was made with field-work on Lower Carboniferous rocks, so that the six-inch scale maps of the northern part of the county, from Berwick down to Wooler and Howick, have now been revised. In the Newcastle district work has been done round Capheaton and Corbridge, taking advantage of boring operations in progress at the time, and a revision of the Coal Measures around the city has begun.

The Lower Carboniferous rocks examined in the north of the county are in more extended sequence than those revised in 1921. In addition to the lower series (the Cementstones and Fell Sandstone, with the Scremerston Coals and Lower Limestones above), the Upper Limestone Group, ranging from the Great or Dryburn Limestone up to the Millstone Grit, is well seen on the coast at Howick. These rocks, when compared with regions farther south, show great attenuation, and as at least two unconformities are present, of unknown amount, a complete correlation with the Tyne area must be deferred until the intervening ground has been examined.

Cementstone Series.—Amongst the excellent sections along the Tweed and its tributaries, estuarine and fresh water remains are common enough, but apart from *Naiadites* and *Spirorbis* are in general too comminuted and fragmentary to be of value. Mr. Tait spent some time collecting plant and fish remains from the most promising localities. Particular attention was given to Lennel Braes, below Coldstream, a spot made classic by the researches of Witham, Milne Home and others; "petrified tree-trunks," with their internal structure well preserved, are fairly common here, along with fragments of *Eoscorpius*. Mr. Fowler also discovered crustacean remains at a new locality, half a mile north of Norham Castle, and amongst them Dr. Peach has identified *Crangopsis eskdalensis* (Peach).[1]

Scremerston Coals.—These seams thin southwards, and between Wooler and Alnwick their outcrop is difficult to trace,

[1] Known also from the Cementstones of the Blackadder section (Berwickshire) though more abundant in the Scorpion Bed of Langholm and Liddesdale immediately above the Fell Sandstone.

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owing to the heavy covering of drift and the paucity of old workings. Mr. Dinham reports that in the Till valley, N.W. of Chatton, they probably lie in a double fold, linked with the great Hetton anticline, though little or no direct evidence of their presence can be obtained. To the north-west, round Etal, the coals are in strong force, and in the past five or six seams have been wrought. Between Etal Colliery and Slainsfield the Fawcett, Blackhill, Main and Cooper Eye coals were mined from 50 to 80 years ago, the last named being the best in quality. At Ford Moss the Main Coal was the chief seam, the others having been wrought on a much smaller scale. This old colliery was again at work from 1910 to 1914, a cross cut having been driven to the Kiln or Diamond seam, between the Blackhill and Main coals: some of the waste material on the bing contains a distinctly marine fauna, including a small branching polyzoan, apparently a new species.

Lower Limestone Group.—The examination of the greater part of the coast section at Berwick-on-Tweed was completed during the 1921 field-season, but one or two doubtful points have now been satisfactorily settled by Mr. Fowler, who reports that the rock seen at low tide N. of the breakwater is the Acre Limestone with, as usual, an abundance of *Saccammina carteri*. At Burgess Cove there is a limestone horizon hitherto unnoticed, which probably agrees with that seen above the higher of the two Howgate Coals (so-called) 1¼ m. S. of Beal: it is a limy greenish marl, packed with *Lithostrotion* and other marine fossils. Mr. Fowler confirms the identification of the Marshall Meadows Limestone with the Dun, while another bed, seen in the cliffs E. of Brotherton's Hole, apparently represents the Woodend Limestone: it is curiously impersistent and seems to die out altogether towards the north.

In the Etal district, additional exposures of the Oxford Limestone have been noted near Brackenside, and on the eastern fringe of High Wood. Other alterations in the mapping have been occasioned by the recognition that the limestone quarried N. of Coldharbour is the Watchlaw, and not the Woodend Limestone. There are excellent sections of the last named seam in the Winterburn quarries, where an 18-inch coal, resting on a hard creamy marl, can be seen 30 feet above the limestone: this same coal, with its accompanying marl, outcrops E. of Woodend farm, and is no doubt the coarse coal used for lime-burning, seen in a similar position several miles to the E. near Fenwick.

The important section of strata between the Watchlaw and Woodend limestones, seen along the old whinstone quarries on Hazely Hill, has been measured. Amongst other information, this section affords the only demonstration as to the relative positions of the Doubster Oil-shale and the Watchlaw Limestone. On the coast S. of Spital the limestone is cut out by an unconformity of some size, and farther south the oil-shale apparently dies away altogether.

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In the North Charlton and Embleton district, Mr. Burnett reports one or two additions to our knowledge of the fine coast sections north and south of Embleton Bay. At Football Hole, there is an unusually clear example of the displacement of a N.E. fault by one trending N.W., while farther south at Cullernose Point, the cliff sections show that a local intrusion of the Whin Sill is later than the east-and-west faults, of which advantage has been taken by dyke-like 'feeders' of the overlying sheet of dolerite.[1] Mr. Gunn had reason to suspect this was the case from the behaviour of the sill in the Belford district, but there conclusive evidence is lacking.

A group of limestone outcrops $2\frac{1}{2}$ miles W. by S. from Embleton village, which have not hitherto been identified, prove to be, in the main, repetitions of the Eelwell Limestone due to strike faults, followed to the S. by the Acre Limestone: these readings have been arrived at largely by palæontological evidence.

In the Alnwick district some preliminary work by Mr. Dinham has resulted in the identification of the Oxford Limestone, with its peculiar '*Girvanella*' nodules, in the river Aln, 1 mile E. of Alnwick. The persistence of this characteristic feature so far south should be invaluable in the interpretation of the doubtful ground S. of the town, where, apart from the Hobberlaw (Woodend) Limestone, no bed below the Eelwell has yet been identified.

Several limestones are seen in the stream section S. of Cawledge East Park, up to the Alnwick–Morpeth main road. The chief one, 12 feet thick, has *Posidonomya becheri* in the overlying shales, and if not the Budle Limestone, cannot be far from that position.

For several miles S. and S.E. of Alnwick the well-known Shilbottle Coal (a first class house coal lying between the Acre or Six-Yard and Eelwell limestones) attains its maximum development both in thickness and quality. The coal has been wrought continuously for a century or more, N. of Shilbottle, and in 1921 the Co-operative Wholesale Society began sinking two new shafts, which are to be 155 fms. deep. These should provide information of considerable geological interest, as they will pass through strata hitherto little known, for the ground is greatly obscured by drift.

The country from Newton-in-the-Moor southwards to the Coquet has been surveyed by Mr. Fowler, Mr. Maden continuing the work down to the Font valley. Throughout this area, continuous outcrops of the Great, Eight-Yard, and Six-Yard (or Acre) limestones are shown on the published maps. These have needed little alteration, for old quarries are numerous, and their evidence is supplemented by workings in the Shilbottle Coal beneath. The Great Limestone is still wrought for road-metal W. of Longframlington. It should be noted that in this region the Eight-Yard or Sandbanks Limestone is richer in *Saccammina*

[1] See also the excellent section by Professor E. J. Garwood in Bateson's 'History of Northumberland,' vol. ii (Howick Parish), Appendix iv, (1895).

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carteri than the Six-Yard (or Acre) Limestone, a condition reversed N. of Alnwick.

The Shilbottle Coal is in good state, down to the Coquet, being from 2 ft. 6 in. to 2 ft. 8 in. thick in the present working pits at Framlington and Healey Cote. Farther south, it begins to thin down, but is in workable condition as far as the River Font near Roughlees. At this point the old map shows the seam crossing the river immediately W. of the railway bridge, but some emendation is required here. It is true that a coal was got in the foundations of the reservoir dam at this spot, but it was 6 feet thick, and apparently of poor quality: some work had been done by 'pillar and stall,' from a shaft 19 feet deep. There can be little doubt that this is the thick, dirty coal, known farther north as the Beadnell Seam, and lying some way under the Eelwell Limestone. The Shilbottle Coal and Six-Yard Limestone probably lie farther down stream, under a cover of drift and alluvium.

During 1921–22 several borings were put down in the vicinity of Forestburn, in search of the Shilbottle Coal. One of these alongside the stream, 500 yards below the inn, passed through 72 feet of boulder-clay, and was then stopped, as it was evidently on the site of a pre-Glacial valley of some size. Another bore proved the Eelwell Limestone (hitherto not recorded in this district) 26 feet thick, with another one 40 feet lower. The cores showed that the last named bed was rich in *Spirifer*, a characteristic of the first limestone below the Eelwell in the Beadnell district.

In the Forest Burn at Wardshill there are excellent sections from the Eight-Yard Limestone down to the top of the Eelwell Limestone. The Six-Yard (or Acre) Limestone, with its characteristic shale above, full of large nodules of clayband ironstone, is well exposed, while the 'Little Limestone,' which is the chief 'mark' for the Shilbottle Coal, can be seen in a shaft alongside the stream. It is a pale hard stone, 2½ feet thick, lying 20 feet above the coal, a position in agreement with northern areas.

A large quarry for 'setts' and road-metal has been opened out in a branch of the Whin Sill, E. of Whitehouses. The working face shows 60 feet of dolerite, capped by a thin cover of soil and boulder clay, never exceeding 10 feet in depth. At the time of the original survey there seems to have been no surface evidence that such an extensive sheet of igneous rock was present. When first discovered 25 years ago the chief clue is said to have been afforded by debris noticed around rabbit holes in the open field.

Upper Limestone Group.—The coast and stream sections S. of Howick, supplemented by recent borings and shaft sinkings to the Shilbottle Coal at Wood House, afford a more or less complete account of the Upper Limestone Group, ranging from the Great Limestone up to the Millstone Grit. These measures attain their maximum development much farther south, towards the Tyne: although it has long been known that they were greatly attenuated in the Howick-Shilbottle district, no reading or detailed account

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of the sequence has been published hitherto. For over 20 miles N.W. of Howick practically nothing is seen of these strata until the Lickar-Lowick area is reached. Here they have been proved in two small synclines, at Lickar and Berrington, where the Lickar Limestone Coal, with the Parrot, Rough and Main coals below, were wrought out many years ago, above the Great Limestone (see Fig. 5). There are good exposures of the Parrot Coal (a micaceous, flaggy seam) in the stream W. of Berrington; and in the Lickar syncline, during the recent revision, a most interesting exposure of the Lickar Limestone was noticed near the mouth of the Lowick Burn. It is a dark, impure limestone, highly fossiliferous. Productí, lamellibranchs, (including a large *Pinna*), *Fenestella* mats, small gasteropods and trilobite tails are noticeably common: the richness and variety of the fauna distinguish the limestone from any other in North Northumberland. This information is of much value in reading the Howick sections. Thin limestones can be seen there, in the shales immediately overlying the Great Limestone, just as at Lowick: 20 fms. higher up a second limestone position (in two 1-ft. beds parted by shales) for which the name 'Cushat Limestone' is suggested, can be seen above the Howick Burn, but they are of normal crinoidal type. Much higher, in fact 80 fms. or more above the Great Limestone, a third bed is seen at several points on the coast section, and its characters at once recall the Lickar Limestone of the Lowick district. There are exposures in the cliffs E. of Howick and for a mile or more along the foreshore S. of Rumbling Kern. Confirmation of the reading is provided by Mr. Burnett's discovery of a parrot coal, exactly like the Lickar Parrot at Berrington, at the foot of the cliff S. of the great Howick Fault, 45 feet below the limestone. The other Lickar coals have almost disappeared, being represented by seams only a few inches thick.

From the mouth of the Howick Burn on to Longhaughton Steel, there is an ascending sequence well up into the Millstone Grit. The first two limestones seen above the Lickar are, as noticed by Professor Garwood, rich in *Productus latissimus:* still higher, in fact immediately beneath the coarse pebbly sandstone of the Millstone Grit Series, two other marine horizons are seen, with an obvious unconformity above (Fig. 5): this transgression increases southwards, cutting out the highest limestone in the Foxton Hall shore section, N. of Alnmouth.

The section at Shilbottle (Fig. 5) is wholly derived from records of bores and shaft sinkings now in progress. Evidence for the upper limestone is given by one bore only, but below this there is ample confirmation of the sequence. It is of interest to note that one of the coals about the Hazon Lee position is a 'parrot,' and no doubt represents the Lickar Parrot of Howick and Berrington. Correlations with the Tyne valley areas are best deferred until the intervening ground has been examined: all that need be said here is that the Cushat Limestone of Howick certainly represents the Little Limestone of the Tyne region.

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and that the Lickar Limestone is the Oakwood Limestone of that area.

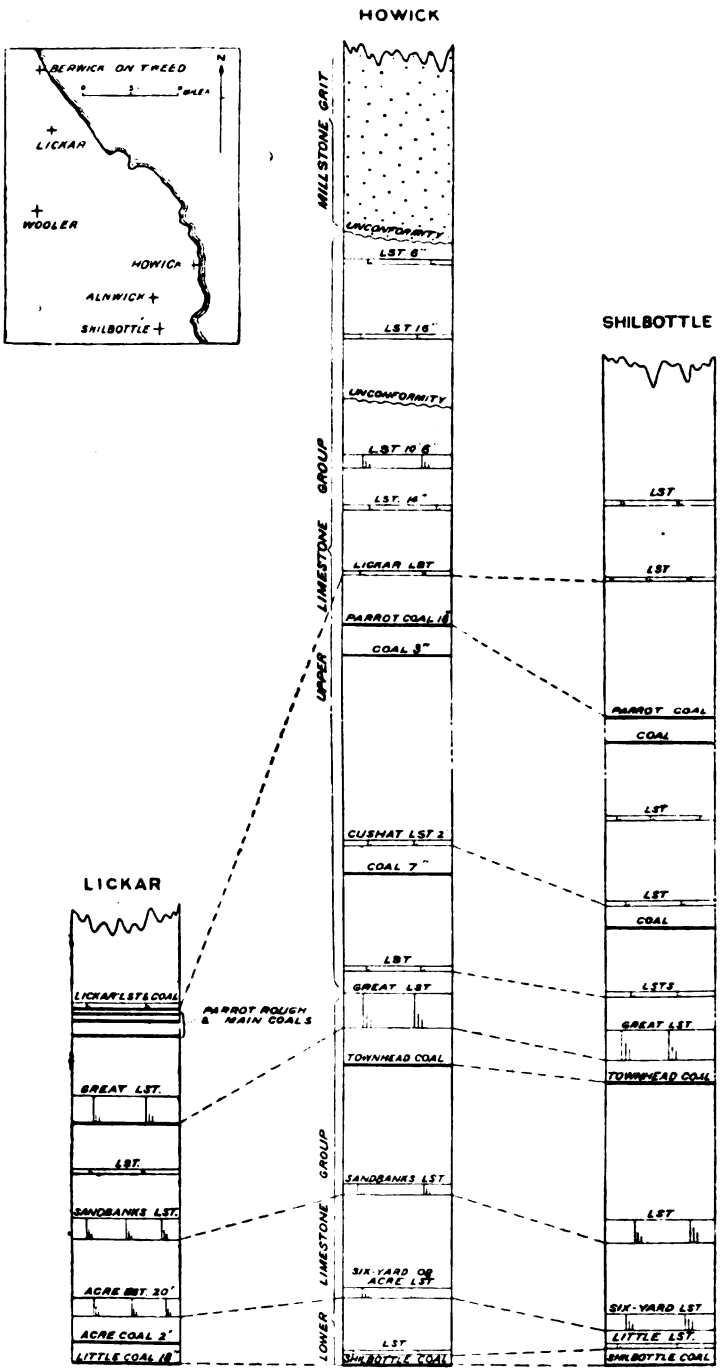

FIG. 5.—*Carboniferous Limestone Strata in North Northumberland.*

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Mr. Fowler and Mr. Maden are still engaged in revision of the Upper Limestone measures in the valleys of the Coquet and the Font: the few sections available are disconnected; the strata undulate considerably, and are much obscured by drift. Mr. Fowler has found a new outcrop of the Little (or Rothley) Limestone of the Tyne, N. of the Coquet, in the streams near Cockshot, but no definite statements as to the rest of the ground are desirable until the work is completed.

Between the River Wansbeck and the Tyne a workable coal, from 2 to 3 feet thick, is found below the Little Limestone. Several borings to this seam have been put down during the past two years in the Capheaton district, and again on the south bank of the Tyne, at Dilston. The cores were examined, and at the same time some revision work was done in the neighbourhood. The borings in both districts have provided a definite account of from 700 to 900 feet of strata, ranging from the Corbridge Limestone down to the Little Limestone Coal, a sequence not well known hitherto. The readings agree very well, although the two districts are 12 miles apart: they have led to some alteration, and several additions, to the maps concerned.

Coal Measures.—During the autumn, work was started on the Coal Measures in the vicinity of Newcastle. Mr. Maden took the area N. of the Tyne, while S. of the river Mr. Burnett began W. of the Derwent. The ground from the Derwent River to the Team valley is being revised by Mr. Anderson.

On the N. side of the city twelve coals or more have been wrought. They are distributed through some 900 feet of strata, and range from the Five-Quarter down to the Brockwell Coal. The ground is traversed by a large fault, down N.W., a continuation of the Ninety-Fathom Dyke, involving the Magnesian Limestone on the coast at Cullercoats. In old days the coals were wrought from the S. up to the 'dyke,' but not beyond, owing to the risk of encountering heavy feeders of water in piercing the fault-line. At the present time the relatively unworked area on the N. side is being actively exploited.

Underground extensions of the dolerite dykes seen on the surface at Walbottle (where it was wrought for road-metal) have been mapped both E. and W. In the workings of the Caroline Pit the dyke stops abruptly, reappearing again about 200 yards farther N. without any visible cause: similar phenomena are not unknown elsewhere, and may be due to the intrusion taking advantage of joint planes in depth.

The Kenton Sandstone, above the High Main Coal, is quarried for grindstones, as also is the freestone at Gosforth (Ouseburn). Fireclays associated with some of the coals are also worked to some extent, but none of them are of exceptional character.

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Mr. Anderson reports that between the Derwent and Team valleys the Productive Measures total about 700 feet, including 8 or 9 workable coals, and they extend down to the Millstone Grit. All the seams are coking coals, save the two lowest (the Victoria and Marshall Green coals) which are house coals. Practically the whole sequence can be seen in the Leap Mill Beck, which runs into the Derwent at Rowland's Gill. The coals seen there are constant over the whole area, the only notable change being in the Busty Coal, whose 4-inch 'Band' increases eastwards to 30 feet. Faults are rare, the largest being 12 fms. down S., in the Byermoor, Andrew's House and Allerdene collieries.

The structure and sequence is thoroughly well known to all the companies concerned, but the nomenclature of the seams is distinctly confusing. While it is not surprising to find several names given to one and the same coal, even in this relatively small area, it is altogether more disturbing to find a particular name (*e.g.*, the Hutton, the Stone, or the Five-Quarter Coal) given to entirely different seams, and this even in adjacent properties: and in at least one case the name 'Five-Quarter Coal' is given to two widely separated seams in a single shaft.

Glacial.—When revising the Tweed valley between Cornhill and Crookham, an extensive series of 'kettled' gravels was noted lying on boulder clay. They are no doubt due to the melting of a considerable sheet of "dead ice" heavily laden with detritus. The ground is covered with irregular accumulations of dirty sand and gravel, interspersed with frequent "kettles," or shallow depressions without natural outlet. Over 50 of these were observed S. and S.E. of Cornhill, there being a particularly fine example at Campfield, half-a-mile S. of the village. The "kames" at Wark and S. of Pallinsburn House are apparently part of the same phenomena, and their heaps of unstratified and unassorted gravels may well be ascribed to the accumulation of surface detritus at the bottom of large crevasses, after ice-movement had ceased. There is evidence that the great Bradford "kame," S.W. of Belford, is of similar origin, as also may be certain mounds of dirty gravel noted by Mr. Maden in the Font valley near Roughlees.

The occurrence on Holy Island of two boulder clays, probably remnants of a single glaciation, was noted in last year's "Summary." They now prove to extend over wide areas in North Northumberland, from the Tweed valley, at least as far as the River Coquet. The lower clay, or true ground-moraine, seems to lie generally in hollows, and is often barely traceable on higher ground, or over projections of the underlying rock surface. Further sections of the ground-moraine have been noted on Holy Island, and on the N.E. side of the Island, a "boulder" of coarse sandstone

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or grit, fully 62 yards long, but no more than 2 feet thick, is exposed in a continuous section along the low cliffs. It lies several feet above the local rock-head, which hereabouts is a well-bedded dark shale. Adhering to the underside of this boulder is a strip of soft coal, which must have been frozen solid with the grit when the mass was torn off by the ice-sheet.

Mr. Dinham has observed traces of drift-filled pre-Glacial valleys, S.E. of Alnwick, and the Shilbottle ridge, E. of the village, is crossed by a fine overflow channel, more than a mile long, at Trobes Dene, between Longdike and Low Buston.[1]

In the Newcastle district Mr. Anderson reports the presence of a large pre-Glacial valley, hitherto unrecorded, which runs S.W. to join the well-known "Team valley washout" at Urpeth Hall. Boreholes along its course reveal a maximum thickness of 200 feet of sand and gravel, the surface-level now being 400 feet above O.D. at that particular point. Mr. Maden has noted that at Heaton a laminated clay is being wrought for brickmaking, beneath 20 feet or so of normal boulder-clay. Some contortion is observable near the top of the brick clay; its origin is still uncertain.

A "buried forest," was noticed 47 years ago on the foreshore at Howick, S. of Rumbling Kern. This is now covered by sand, but a fresh exposure is visible at the present time a mile farther S. at the mouth of the Howick Burn. The usual tree trunks (some still in their position of growth) of oak, birch, and alder, can be seen, along with hazel nuts. They rest in a peaty soil, in which small fresh water shells are occasionally found. This exposure is only visible at low tide.

(B)—SCOTLAND

Coalfield Revision

1. Ayrshire Coalfield

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Work was continued in Central and Northern Ayrshire and in the part of Renfrewshire which is included in Sheet 22.

Old Red Sandstone.—Mr. Simpson reports that on Tincornhill and the adjacent high ground the Lower Old Red Sandstone consists of sandstones sometimes massive, but more often flaggy and usually greenish-brown. The grains are angular,

[1] First noted by Dr. J. A. Smythe. See *Trans. Nat. Hist. Soc. Northumberland*, etc., vol. iv. (1909–1913), p. 107, and Map No. 1 (Channel No. A 21).

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and obviously felspathic. Clay galls are common, and are often in layers parallel to the bedding planes. The general dip is to W.S.W. at a gentle angle, but false-bedding is sometimes very marked. The series includes a conglomerate, with well rounded pebbles of quartz and flint, which forms the summit of Blacksidend.

The same varieties of sandstone are present in Blackside, Auchinlongford, and Wedder Hills, mapped by Mr. MacGregor. In both areas the finer sediments have been hornfelsed by the action of igneous intrusions. This may be due to an underlying plutonic mass, continuous with that which rises to the surface in the Distinkhorn area farther north. In this district, numerous sills and irregular masses of intermediate and sub-basic type, and dykes of felsite and lamprophyre cut the sedimentary rocks.

In the burn at Burnhouse these sediments underlie the Upper Old Red Sandstone. The latter consists largely of yellow, or chocolate-coloured sandstones. They are very friable, and often decidedly calcareous. Interbedded with the sandstones are very green and brown marls; there are also frequent beds of nodular cornstone, and thin bands of conglomerate.

The two series are not seen in contact, but their dip is similar, both in degree and direction. The lithological difference, however, of the types makes separation easy; and in the overlying series the numerous intrusions and the hornfelsing which characterise the underlying sediments are both absent. It is clear that before the deposition of the Upper Old Red Sandstone, the lower series was invaded by igneous rocks, and subjected to a certain amount of erosion.

Near Auchmannoch, Mr. MacGregor has found that the types of Upper Old Red Sandstone rocks are much the same as those in the area farther south. Cornstones are here well developed, and are exposed in many disused quarries. These cornstones consist mainly of more or less horizontal bands of irregular calcareous concretions in a matrix of impure sandstone. In the best limestones the whole rock consists of such concretions, with some cherty material. A very fine example is seen in the Old Craigleith quarry, east of Lawdyke, where the longer axes of the concretions show a tendency to be vertical.

Calciferous Sandstone Series.—South of the River Irvine the volcanic group in this series is thin or absent. The underlying Cementstone Group may also be absent, but in the areas mapped this year, some miles to the north and to the east of Sorn, it is typically developed.

The base of the Cementstone Group was noted by Mr. Simpson in the burn-section east of Tincornhill at a point west of Burnshield. It is marked by a bed of brown marls containing fish scales and entomostraca. This bed occurs only 10 feet

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above a cornstone of Upper Old Red Sandstone type, and is succeeded by grey flaggy micaceous sandstones and thin cementstones, one of which is conglomeratic. The passage-beds between the Upper Old Red Sandstone and the Cementstone Group have also been studied by Mr. MacGregor, in the Auchmannoch neighbourhood, where several burn-sections show an apparently conformable passage between the two groups. In its basal part the Cementstone Group contains (1) red marls, which alternate with greenish marly shales, and (2) thin bands of flaggy, sometimes micaceous sandstone, which replace the usual thin bands of cementstone. These layers often contain green clay galls; they commonly show ripple-marks and sun-cracks. Another feature of the base of the series is (3) the development of bands of conglomeratic limestone, made up of rounded fragments of cementstone. These fragments were probably derived from previously solidified cementstone, and like the sun-cracks and ripple-marks, point to extremely shallow water conditions.

The overlying volcanic group is very thin in this part of Ayrshire, and its outcrop cannot always be traced. On the north bank of the River Ayr, however, near the farm of Hole, Mr. Simpson observed a fossiliferous limestone belonging to the Carboniferous Limestone Series resting on an altered lava. The type of alteration resembles that which has affected some of the Millstone Grit lavas in north Ayrshire. About 10 feet of lava is seen; the lower part is brown or greenish in colour, and platy, owing to the parallel arrangement of felspar crystals, which, as in the Millstone Grit lavas, is not a genuine flow structure. Towards the top of the flow contemporaneous weathering has altered the rock into a material extremely like the Bauxitic Clay of Northern Ayrshire. The lower part of this clay contains grains of sphaerosiderite, but the upper part (twelve to sixteen inches thick) is without iron carbonate, and pure grey or white in colour.

Carboniferous Limestone Series.—Mr. Anderson has mapped an area of Carboniferous Limestone about three miles to the south of Galston. The central division, or Limestone Coal Group, here contains a coal which in one place is 2 ft. 6 in. in thickness, and locally, has been opened up in old crop workings.

Another small area of rocks belonging to this group is intersected by Burn o' Need, about a mile to the west of Blackside. There are old coal workings close to the burn. The 'Statistical Account of Scotland' states that the coal was 5 ft. in thickness.[1] Mr. MacGregor reports that a coal is now seen which is between 1 ft. 6 in. and 2 ft. in thickness, but it may be a short distance above that which was formerly worked.

[1] Vol. xx, 1798, p. 138.

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Mr. Simpson has found that the limestones seen in the River Ayr, above Sorn, include representatives of both Upper and Lower Limestone Groups. Several seams of coal are exposed in natural sections in the Limestone Coal Group, but only one of them, which is three feet in thickness, seems likely to be workable. The coals formerly worked near Sorn village are not now visible.

In the northern part of one-inch Sheet 22, the stratigraphy of the Lower Limestone Group, and the Calciferous Sandstone sediments, has already been fully investigated.[1] These strata are there well developed, and include the following beds :—

Hosie Group, consisting of blaes with 3 or 4 thin limestones, and a thin fireclay - - - - - - -	Up to 17 fms.
Dockra (Hurlet) Limestone and Coal - - - - -	„ 7 „
Upper Calciferous Sandstone sediments consisting of fireclays and marls with from 1 to 4 limestones. Volcanic detritus at the base overlies the Calciferous Sandstone lavas - - - - - - - - - - - -	„ 30 „

In the south-east part of the one-inch Sheet, where the above strata are much curtailed by overlap on to older rocks, the correlation of the various beds from place to place, and with those of the area to the north, has been carried out by Mr. Richey.

At Stewarton, the Upper Calciferous Sandstone sediments are almost entirely overlapped by the Dockra Limestone. The latter is itself greatly curtailed east-north-east of Stewarton, and is only 5 feet thick, in the Annick Water, west of Broadland. Farther eastwards, at Laigh Clunch, the Dockra is entirely absent, and the lowest Hosie limestone is the first marine position met with above the beds of volcanic detritus. This can be correlated with certainty with the first Hosie limestone found above the Dockra in the Annick Water exposure by a distinctive fossil bed immediately above it.

The Dockra Limestone in the Stewarton district, and generally throughout this one-inch Sheet, has a peculiar, uneven, bleached top, which is often pierced by rootlets and overlain by a thin bed of greenish marl or fireclay. It has also been recognised by this peculiarity in the Galston district. North of Galston the limestone is mixed with volcanic ash, beds of which are also found below the limestone. This denotes continuance of the volcanic activity of Calciferous Sandstone times in this district to a comparatively late date.

The Hosie Group near Stewarton includes three limestones, but north of Galston only the two upper limestones of this series

[1] P. Macnair, 'The Hurlet Sequence in North Ayrshire,' *Trans. Geol. Soc., Glasg.*, vol. xv, 1914, p. 200.

R. G. Carruthers and J. E. Richey, 'The Lower Limestones of Renfrewshire and North Ayrshire: a comparison and correlation,' *ibid.*, p. 249.

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were found. These are exposed in the Hag and Polbaith Burns as well as at Inchgotrick, south of Kilmarnock.

The Top Hosie Limestone is associated in the Stewarton district, and also at Inchgotrick, with blaes containing *Posidonomya corrugata*. This is the characteristic fossil of the Top Hosie horizon which has been traced over a wide area by Prof. Macnair.

At Inchgotrick, this limestone is a thin cement-like irony band with few fossils. A similar thin band is found in this position in the Polbaith Burn and near Wellhill, north of Galston, where it is overlain by a band of ironstone succeeded by a coal seam. This succession furnishes a good means of distinguishing the horizon in the Galston district. The Top Hosie can thus be recognised in Burn Anne, near Cessnock Castle, where certain strata have long been known to be absent at the base of the Carboniferous system. Beds of limestone almost immediately overlie the Upper Old Red Sandstone, which includes a cornstone. The Calciferous Sandstone lavas and cementstones are entirely absent. The extent of the unconformity has now been determined as the limestones include only the two upper bands of the Hosie Group. A thin conglomerate with small pebbles of chalcedony and of cornstone marks the unconformable base of the Carboniferous Limestone.

Millstone Grit.—Recent work in North Ayrshire has shown the constancy and extent of the Millstone Grit volcanic series. In the Gailes bore (half-a-mile south-east of Gailes Station) the lavas are 90 fms. in thickness. This indicates that they might be expected to have an extensive outcrop. Mr. Anderson has found that they are present at the surface for quite a mile to the north and east of Barassie, and form a broad belt running east through Symington, whence they extend in a narrowing strip along the northern margin of the Mauchline basin. In part these lavas had previously been mistaken for intrusive rocks. The Craigie Hill mass, which borders the lava area, is an intrusion, It extends as far as Catcraig Quarry, and is intersected by minor intrusions of a fine-grained basic rock with a distinctly glassy character.

Coal Measures.—Areas of Coal Measures have been mapped by Mr. Simpson to the west of Old Cumnock, and by Mr. Anderson and Mr. Eyles in the neighbourhood of Dundonald and Prestwick. The Old Cumnock area is mainly drift-covered, but a section of productive Coal Measures is seen in the River Lugar between Old Cumnock and Lugar village. Most of the workable seams crop out on the banks, but were formerly rather poorly exposed. During the strike in 1921, however, most of the outcrops were opened up, and the clearer exposures have enabled many corrections to be made in the published map.

The Prestwick area is also drift-covered, and practically the only rocks exposed are igneous intrusions, as in the Dundonald and Clevance Hills. These consist of a thick sill of teschenite

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dolerite, which is in a higher position than the Coal Measures to the north-west, west, and south. This sill may also form the promontory which protects the harbour at Troon. Its horizon is not accurately known, but a coal which was worked on a small scale near Colleman in the underlying sediments is supposed to have been the Splint or Hurlford Main.

Several unrecorded sills and dykes have been mapped by Mr. Eyles between Prestwick and Tarbolton. A thick sill exposed in a stream bed 600 yards E.N.E. of Townhead, near Monkton, shows much vertical variation.

Mauchline Volcanic Group and New Red Sandstone.—A considerable area of these rocks has been mapped by Mr. Simpson near Ochiltree, where an intercalation of sandstone occurs in the volcanic series, probably near its base. Underneath the sandstone is a thick ash, which may form the base of the volcanic group. The junction of the latter with the underlying Barren Red Coal Measures, is nowhere seen in this district.

Glacial and Post-Glacial.—Further occurrences of shell fragments in boulder-clay have been noted in the Sorn district by Mr. Simpson.[1] The highest occurs in a stream section 100 yards north of Burnshield (east of Tincornhill, 700 feet above sea-level).

A mile farther west, near Westown, very finely glaciated surfaces are visible at the border of a quarry. The striae occur in sets which run W. 15°–25° N., W. 35°–40° S., and S. 10° E., but in no case could the direction of ice-flow be determined. On the moor, west of Burnhouse, there are crossing striae which may correspond to the first and last of these directions.

Glacial overflow channels have been found by Mr. Anderson to cross the ridge of the southern part of the Dundonald Hills, near Clevance and Harpercroft, and have an eastern drainage. This suggests that at one time the ice pressed against these hills from a western direction.

In the coastal area to the south of Troon, Mr. Eyles has mapped a raised beach plain at the 35 or 45-ft. level. Raised beach material also exists at higher levels, and chiefly just below the 100-ft. contour. It usually consists of a thin gravel capping, which may often be seen to overlie boulder-clay. A good section exposed in the burn south of Brieryside, is:—4 feet coarse gravel, over 4 feet laminated reddish brown sand, with large rounded boulders, and fine pebbly layers, resting on laminated sandy clay; base not seen.

These beds appear to be relics of the 100 or 110-ft. platform of marine alluvium of northern Ayrshire, but the deposit is local.

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[1] See 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 78.

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2. Central Coalfield

Muirkirk District

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Mr. Wilson continued the revision of the much folded and faulted Muirkirk Coalfield. In the 'Summary of Progress for 1921' mention was made of the important fault forming the northern margin of the field; this has now been proved to extend continuously from the coast near Girvan to beyond the head of the Pockmuir Burn. To the south and east the boundary between the Carboniferous rocks and older formations is in some places a fault, but elsewhere the Carboniferous rocks rest conformably on the Upper Old Red Sandstone. The average width of the coalfield is about one and a third miles. The strata are thrown into small folds with a general N.N.E. trend, and are traversed by numerous faults with directions varying from W.N.W. to E.N.E. Many dolerite dykes occur, some of which accompany the lines of faulting.

Upper Old Red Sandstone.—Along the southern margin of the area the base of this series is a coarse conglomerate consisting mainly of rounded pebbles of Silurian greywacke and a few quartzites. It is of a reddish or greenish colour, and is often characterised by much calcite-veining in the matrix. A thin cornstone occurs a few feet above the conglomerate. On the northern boundary, however, the conglomerate has not been noticed, but one or two thick bands of cornstone occur just above the base of the series.

Calciferous Sandstone Series and Lower Limestone Group.—The Calciferous Sandstone volcanic series which is widely developed in North Ayrshire does not occur in the Muirkirk area. Along the northern edge of the area a thick bed of variegated sandy marls with bands of cementstone, is found overlying the Upper Old Red Sandstone. This Cementstone Group has been proved to extend from the Mossy Burn in the west, to Monkshead, above Glenbuck, on the east. Along the southern boundary, however, the Cementstone facies has not been noticed, and the limestone-bearing strata are found to rest directly on yellow sandstones, which pass down gradually into the Upper Old Red Sandstone. As yet it has not been possible to draw a line between the Calciferous Sandstone Series and the overlying Lower Limestone

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Group. The general succession, which is much the same on both sides of the area, is as follows :—

Macdonald -	Limestone and limy blaes (very fossiliferous)	20 to 30 ft.
	Strata (sandstone and blaes) - - -	5 „ 10 „
	Limestone - - - - - - -	9 in.
	Coaly blaes and fireclay - - - -	5 ft.
	Limestone (crinoidal) - - - - -	1½ „ 2 „
	Pyritous nodular blaes - - - -	10 „ 15 „
	Fakes - - - - - - - -	2 „ 8 „
	Black blaes (sometimes variegated with red streaks).	10 „
	Sandy fireclay and sandstone - - -	3 „ 9 „
Hawthorn -	Nodular limestone (corals and *Productus*) -	1 „ 9 „
	Limestone and limestone blaes - - -	up to 12 „
	Small gap - - - - - - -	? 6 „
	Limy blaes and limestone bands - -	up to 12 „
	Sandstone - - - - - - -	? 40 „
Wee -	Limestone - - - - - - -	2 „ 3 „
	Sandstone.	
	Cementstones (on the north margin only).	

The Wee Limestone usually yields a few fossils. In the Stottencleuch Burn and above Monkshead on the northern side of the area, it is creamy and nodular. Along the southern margin, however, it is grey and sandy. Owing to the fact that the complete sequence between the base of the Hawthorn Limestone and the underlying limy blaes with limestone bands has not yet been seen, it is impossible to state whether the latter represent a separate limestone horizon or are simply the lower portion of the Hawthorn. The top of the Hawthorn Limestone is often exposed. It can be recognised by its nodular character, and by the presence of large *Productus*, and masses of *Lithostrotion junceum* up to 2 feet in thickness. The appearance of the bed suggests that it represents a coral reef, which was gradually rising from the sea and approaching to land conditions. The occurrence of filled-in sun-cracks in the immediately overlying sandy fireclay adds strength to this hypothesis. It is not yet possible to correlate the Hawthorn with any of the limestones of Ayrshire or the Central Coalfield; it has, however, certain characteristics, such as the nodular top, which suggest its identity with the Dockra of Ayrshire. An excellent section of the coral reef is to be seen in the old quarries near the Ashaw Burn.

Some of the thin limestones which occur between the Hawthorn and the Macdonald may represent the Lower Hosies of Ayrshire, and no doubt the Macdonald is equivalent to the Upper Hosie Limestones. Until the fossil evidence is more complete it is, however, unwise to make any definite correlations.

The Limestone Coal and Upper Limestone Groups.—The section of the Limestone Coal Group in the Auldhouse Burn shows that the basal portion consists mainly of shale and the upper portion, in which the coal seams occur, of sandstone. Farther west, in the small burn above Wellwood Pit, the shale and associated ironstone which overlie the Macdonald Limestone are seen to contain *Lingula* and a few other fossils.

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The members of the Upper Limestone Group are well-exposed in the Garpel. Five limestones occur. The Index is not now exposed, but its position is marked by an old quarry. In other parts of the area it is often readily recognised by the presence of numerous shells of *Productus latissimus* in the top part of the seam. A sandy limestone with a few shells occurs a short distance above the Index. The middle limestone is about 6 ft. thick, massive, and is exposed under the old bridge on the road to Wellwood Pit. A little farther down-stream, about 30 feet of highly fossiliferous limy shales with bands of limestone occur. They are underlain by black fossiliferous blaes and parroty blaes, and overlain by a false-bedded sandstone, 40 feet thick. This in turn is followed, in upward succession, by a coal and by the overlying Blue Tour Limestone. The latter bed is well-exposed under the bridge on the G. & S.W. Railway line to Ayr.

Millstone Grit.—The massive bed of sandstone which occurs a few fathoms above the Blue Tour Limestone is probably of Millstone Grit age. A bed of fireclay is exposed, on the down-throw side of a fault, in the small burn near the top of Hawkshaw Plantation. It is about 10 feet in thickness and is usually of a reddish colour. Certain grey bands associated with the seam have many characteristics of the Ayrshire Bauxitic Clay.

Igneous.—In the small burn, above Wellwood Pit, a felsite dyke which is intruded into Lower Old Red Sandstone rocks, is cut off by a fault which brings down the Macdonald Limestone directly against the dyke.

Glacial.—Great spreads of glacial sand and gravel are found on both sides of the Ayr valley near Muirkirk. They occasionally occur in the form of mounds, but terrace-like formation is the more common. An excellent section in a sand mound is to be seen in the pit, on the railway side, 200 yds. south-west of Auldhouseburn Pit. The material is mostly fine-grained, with occasional pebbly and coaly layers. It is used for pig-iron casting-beds.

COALBURN DISTRICT

Mr. Ross continued the revision of the Downtonian and Lower Old Red Sandstone rocks to the north-west of the Douglas coal-basin, and the Carboniferous sediments in the Lower Nethan and Scots Burn valleys.

Downtonian and Old Red Sandstone.—On the north side of the valley of Kype Water, 160 yards S.W. of Townend Farm an exposure was noted of the Quartzite Conglomerate forming Zone 3 of the Downtonian Series.[1] The conglomerate is here overlain by red sandstone flags dipping north at 18 degrees. This indicates a slight extension northwards of the outcrop of the upper band of the conglomerate. A recent exposure of

[1] 'Silurian Rocks of Great Britain,' vol. i Scotland (*Mem. Geol. Surv.*), 1899, p. 68.

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purplish micaceous sandstone of Lower Old Red type dipping east at 15 degrees, was noted 180 yards E.S.E. of Townend Farm. This serves to define more accurately the course of the great north and south fault which separates Downtonian rocks from the Old Red Sandstone. On the west side of this fault, from a point about 200 yards west of Juanhill, the directions of dip of the Downtonian rocks radiate outwards, north-west, north, and north-east, at angles from 15 to 20 degrees, showing these to be folded in an anticline pitching gently north. The axis of the fold passes southwards through a point about 400 yards west of the confluence of Hareshaw Burn and Kype Water, the dips of the flaggy shales and sandstones of Zone 1 of the Downtonian Series exposed in the bed of the former varying from N.N.W. to N.W. at angles from 10 to 20 degrees, while similar strata appearing to the east in the bed of the latter dip N. and N.N.E. at angles from 5 degrees to 15 degrees. From this point the axis swings slightly east of south and is truncated by the fault to the west of Auchrobert Snout. Here the Quartzite Conglomerate band reappears to the east of the fault and its outcrop can be traced in a broad crescent eastwards through Lower Waterhead and then southwards, passing just east of Cleuchhead.

Pre-Carboniferous Igneous Rocks.—A set of igneous intrusive rocks varying in type from dark red coarse-grained hornblende-felspar-porphyry to salmon-pink fine-grained quartz-porphyry appears above the Quartzite Conglomerate of Zone 3, good exposures being seen just south of Goslington, on Auchrobert Hill, and on the heights between North and East Brackenrig. Where their relations can be determined, these intrusions are sill-like in form, either parallel with the bedding of the sediments or cutting them at low angles.

Carboniferous.—The re-examination of the faulted belt of Carboniferous rocks in the valley of the Scots Burn and in the Lower Nethan was continued. In the small western tributary of the former, 500 yards S.W. of Stockhill, good exposures occur of white and red sandstones and grits with subordinate marly bands dipping N.E. at angles from 18 to 30 degrees. These appear to rest unconformably upon the flaggy red sandstones of Lower Old Red type exposed a few yards farther west dipping east at about 40 degrees, and to represent shore deposits of Lower Calciferous Sandstone or late Upper Old Red Sandstone age. Farther east, in Scots Burn, 350 yards S.S.W. of Burnside, occurs a band of variegated pebbly conglomerate about 18 inches in thickness containing pebbles of chert, quartz and red sandstone.

To the east of this exposure the strata are of more normal Calciferous Sandstone aspect, with occasional bands of cornstone, and, near the top, several thin bands of limy marl with marine organisms. In the Lower Nethan north-west of Dalquhandy Farm, are exposed two thick bands of cornstone with green and red marl between, dipping east at 25 degrees. These are comparable with the "Foul" or Nodular Limestone recorded

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elsewhere in the district several fathoms below the "Big" Limestone of Auldton and Auchren.

The "Big" Limestone of Auldton, which is characterised by the presence near its top of *Productus giganteus* (the typical form) is exposed in the Nethan 400 yards north of Old Stockbriggs. Here it dips N.N.E. at 20 degrees, and about 160 yards downstream is an exposure of the "Wee" Limestone of Auldton about six feet thick, with crinoidal shales above and an eight-inch coal below. About 200 yards farther downstream, appears an outcrop of limestone and fossiliferous shales about 12 feet thick containing *Ambocoelia urei*, which is common at the Blackhall Limestone horizon, and found elsewhere in the district in the "Main" Limestone of Coalburn. These limestones apparently follow upwards in normal sequence. The "Big" Limestone reappears in the Logan Water S.S.E. of Whiteside, just east of the fault bringing it down against the Lower Old Red Sandstone to the west, and from this point it follows the course of the Nethan immediately east of the fault for about three quarters of a mile. An exposure of the "Wee" Limestone about 5 feet thick, with a six-inch coal below, was seen about 30 feet above the "Big" Limestone in the steep east bank of the Nethan west of Auchlochan House. The next exposure of the "Big" Limestone occurs in the east bank of the Nethan just east of Auchlochan Bridge. From here downstream to the point where the boundary fault crosses the Nethan S.W. of Gateside, the strata appear to belong mainly to the Lowest Division of the Carboniferous Limestone Series, with the exception of a small faulted inlier of Lower Old Red Sandstone unconformably overlain by Calciferous Sandstone sediments exposed in the bed of the Nethan east of New Trows.

Four hundred yards W.S.W. of Auchlochan Bridge, a few yards above the weir across the Nethan, a well-marked W.N.W.–E.S.E. fault brings down Upper Limestone strata. From this point to Auchlochan Bridge where another fault with S.S.E. downthrow cuts it out, the Index Limestone is repeated three times in the bed of the Nethan in a sharp anticline and syncline. In the core of the syncline appear two outcrops of a higher limestone about 4 feet thick with a thin coal below it. Another outcrop of the Index Limestone was noted in Johnshill Burn, 100 yards downstream from the public road. The following is a slightly generalised section of the Index Limestone from the outcrops west of Auchlochan Bridge :—

Limy blaes, faky at top	15 ft. seen.
Crinoidal limestone containing *Productus latissimus* at top	1 ft. 6 in.
Crinoidal shale	9 in.
Massive dark blue limestone, ochreous on surface, weathering in rectangular blocks	4–5 ft.
Rooty fakes and fireclay with coaly blaes 6 inches from top	15 ft. seen.

Post-Carboniferous Igneous Rocks.—A fine-grained basic dyke probably of Tertiary age, about 30 ft. wide, crosses the bed of the Kype Water, just north of the Kype Reservoir dam, and its

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continuation to the south-east is exposed in Logan Water, 500 yards east of Dunside. A basic dyke passes about 500 yards west of Dalquhandy Colliery, and accounts for the burnt outcrop of the Ell Coal running near it for about 300 yards northwards.

Glacial.—A notable series of sand and gravel mounds extends on the high ground just above the 900-ft. contour from half a mile N.E. of W. Craighead, across the Upper Nethan valley S.E. to Stockhill. Eastwards from there the country is thickly covered with stiff greyish brown boulder-clay. Associated with these gravel deposits is a set of shallow glacial drainage channels which trend S.S.E. on the heights around Greenfaulds, while their continuations in the high ground east of Stockhill tend to swing round S.E. towards the Coalburn valley. They are well defined, and cut sharply into the boulder-clay to a maximum depth of about 35 feet. The lowest and best marked of them is now occupied by the railway from Dalquhandy Colliery.

STRATHAVEN

Revision of the area of Calciferous Sandstone lavas, begun by Mr. Dinham and reported in the 'Summary of Progress for 1915,' has been continued by Mr. Phemister, who finds that the lavas are olivine-basalts of a variety intermediate between the Dalmeny and Dunsapie types. The variations are considerable, but no typical Markle or Craiglockart types are found, and similarly, classification as porphyritic or non-porphyritic is in some cases quite arbitrary. Amygdaloidal varieties are common, and spheroidal weathering is frequent. Other flows of the same types are comparatively fresh. Terraced features due to flows are rare, indistinct, and of very small extent, and a continuous covering of boulder-clay, gravel, or peat combined with the lack of outstanding characteristics in the lavas themselves, precludes accurate correlation over any considerable area.

On the right bank of the Calder Water, just below its junction with the Little Calder, there is a small exposure of typical yellow weathered trachyte. It is probably a flow, but its relations to the basalts are not seen. In the same neighbourhood there are two bosses, one of albite-porphyry, which forms a "craig" on the east margin of Mossmulloch, and another of mugearite(?) forming the small hill called the Law.

CLACKMANNAN

Mr. Read has continued the re-mapping of those parts of the volcanic rocks of Lower Old Red Sandstone age of the western end of the Ochils which fall within the six-inch sheets of the Clackmannan Coalfield.

The steep face of the Ochils between Menstrie and Bridge of Allan is formed by a series of conglomerates, agglomerates, and andesite lavas which dip gently northwards. As mentioned in last year's 'Summary of Progress,' the volcanic pile is cut up into blocks by powerful N–S faults. A sequence of some thirty

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lavas, together with intercalated conglomerates and agglomerates, has been established. Intrusive rocks in this area are limited to (1) a few narrow, much decomposed dykes of intermediate or basic composition, (2) a conspicuous blotchy pink felsite seen immediately west of Dumyat, (3) several small masses of basic rock occurring above Blairlogie, and (4) the glassy hypersthene-andesite of Airthrey described by Dr. J. S. Flett[1] and Prof. W. W. Watts.[2]

The Carboniferous rocks lying between the Blairlogie Ochils and the River Forth are concealed by the Carse clays of the 50-ft. Raised Beach. What appears to be a new section of Millstone Grit has been found in the River Devon between its junction with the River Forth and the village of Cambus. Here, at low tide, fireclays and sandstones of Millstone Grit type are seen dipping gently N.N.E.; according to bores at Cambus the horizon is low down in the Millstone Grit. No trace was found of the "Mountain Limestone" seen by Robert Bald[3] a century ago "in the Devon near Cambus"; if Bald's identification as limestone of the rock seen by him was correct, it is possible that he was dealing with one of the thin marine bands in the Millstone Grit.

Mr. Haldane extended the revision of the Clackmannanshire Coalfield to the north-east of Alloa along the valley of the River Devon from Tillicoultry to Dollar and Blairingone. The area is bounded on the north by the great Ochil Fault.

Coal Measures.—The western portion of the area in the neighbourhood of Tillicoultry consists of Coal Measures strata forming the eastern side of the Devon basin. East of this the region appears to be much faulted and is dotted over with long-abandoned shafts. A few sections are seen in the small streams to the south of the Devon, but these are poor and the horizon of the strata cannot be identified with certainty. The Alloa Cherry Coal, dipping north, crops out near the foot of the Bessie Glen, south-east of Tillicoultry, and reappears at the surface on the high ground to the south. In the Melloch Glen, 1,100 yards east of Bessie Glen, another outcrop of the same seam occurs.

Two small isolated basins of Coal Measures occur at Dollar and Blairingone. The section of the eastern portion of the Dollar field at Lawhill is reported to extend from about the position of the Nine-foot Coal down to the Coalsnaughton Main; (Vertical Section 4, Sheet 5. Geol. Survey, Scotland, 1877), but no recent information is available and it is not known if there are workable seams below the Coalsnaughton Main as in the Alloa and Clackmannan areas. This also applies to the Blairingone basin where coal workings were in progress nearly a hundred

[1] J. S. Flett, 'A Hypersthene-andesite from Dumyat (Ochils),' *Trans. Edin. Geol. Soc.*, vol. vii, 1899, p. 290.

[2] W. W. Watts, in Sir A. Geikie's 'Ancient Volcanoes of Great Britain,' vol. i, 1897, p. 276.

[3] Robert Bald, 'The New Statistical Account of Scotland,' vol. viii, 1845, p. 24.

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years ago. A fireclay about three fathoms below the Coalsnaughton Main was mined about the years 1906–7. West of the town of Dollar, the coals have not been proved though it is likely that the seams in the Lawhill area extend west for some distance.

Millstone Grit.—In this neighbourhood the Millstone Grit appears to be thinner than in the Clackmannan district. Data are scanty, but an estimate of the thickness around Vicar's Bridge and Lawhill gives 115 fathoms compared with 150 fathoms near Clackmannan. In the neighbourhood of Sheardale House a large N.W. fault brings the lower beds of the Millstone Grit against Coal Measures strata. Sections in Byles Cleugh Glen and Rackmill Glen show a limestone taken as the equivalent of the Castlecary Limestone at the base of the Millstone Grit.

Two miles east of Dollar at the Vicar's Bridge the Devon flows through a rocky gorge, but the banks are thickly wooded and the section is much obscured by undergrowth and screes. In the vicinity of the bridge there are numerous refuse heaps and a few old mine openings to an ironstone formerly wrought for the Devon Ironworks. The ironstone is probably some 40 fathoms above the Vicar's Bridge Limestone but no records are available. About 250 yards east of the bridge is the Vicar's Bridge Limestone which has been extensively wrought in the past, and is considered to represent the Castlecary or Levenseat Limestone. As far as can be seen now it consists of about five feet of limestone and calcareous sandstone with a sandstone pavement and roof.

Carboniferous Limestone Series.—East of this limestone, strata of Carboniferous Limestone age are seen for about 350 yards until cut off by a large S.E.–N.W. fault which is probably a branch of the main Ochil Fault. On the east side of this fault, near Arndean, there is an intrusion of dolerite about 60 yards wide, much weathered and veined with calcite. The sediments on the east side of the dyke are much baked and disturbed, but farther east they pass downwards through a Cementstone facies into Upper Old Red Sandstone.

Glacial and Recent.—Boulder-clay covers most of the area south of the Devon valley. No glacial striae have been noticed. North of the Devon the boulder-clay is obscured or mixed with screes and hill wash from the south face of the Ochils. Just east of Tillicoultry a prominent series of sand and gravel mounds projects into the valley. The Cunninghar sand pit is situated in one of these mounds and shows a good sect on, over 50 feet high, of well-bedded alternating layers of sand and gravel. The beds dip to the east and north-east at angles of 8 to 10 degrees and false bedding is frequent. Much of the sand is very fine-grained, buff coloured, with coarser lenticular layers, while the gravel, in bands up to 10 feet thick, is composed of well rounded pebbles of igneous rock derived from the Ochil Hills. Occasionally there are thin bands in the gravel composed of fragments of coal with very much smaller pebbles of igneous material. This series of

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kames stands out boldly across the valley of the Devon which is here constricted to a narrow passage between two sandy spurs. An area of sandy gravel extends for nearly two miles along the north of the valley from north of Tillicoultry to east of Harviestoun Castle. Another expanse stretches east from Dollar and along both sides of the Devon.

The River Devon flows in a winding course through an extensive plain of alluvium west of Vicar's Bridge. This is interrupted by the alluvial cones upon which stand Dollar and Tillicoultry, and also by the kame at Cunninghar.

West of the kame, the alluvial flat merges into the Carse clays of the 50-ft. Raised Beach, the margin of which may be traced at a few places near Tillicoultry. Traces of the 100-ft. Raised Beach are occasionally seen here and also along the valley towards Dollar. Just west of this town where the alluvial cone merges into the flat there is a deposit of fine red laminated brick-clay similar to those found east of Alloa and north of Clackmannan. This deposit near Dollar where the clay was formerly wrought is probably a relic of the 100-ft. Raised Beach.

3. West Highland District

E. B. Bailey, M.C., B.A. District Geologist.
J. E. Richey, M.C., B.A. Senior Geologist.
V. A. Eyles, B.Sc.
J. B. Simpson, B.Sc. } Geologists.
A. G. MacGregor, M.C., B.Sc.

Lewisian Complex: Tiree

The mapping of Tiree has been completed during the past field season.

Topographically Tiree falls into three divisions, separated by blown sand. Mr. MacGregor mapped the northern half of the western area, and Mr. Simpson its southern half. Mr. Eyles mapped the central area, with the exception of the Gott Bay para-gneisses which had previously been mapped by Mr. Bailey.

Orthogneisses.—Three varieties are recognisable:—

(1) Grey biotite-hornblende-gneisses.
(2) Black hornblende-schist.
(3) Pale grey, pink or red granite-gneisses.

(1) This is the prevalent type and is in the main a well-foliated quartz-felspar-hornblende rock in which biotite is usually present and sometimes conspicuous.

(2) The black hornblende-schist is much more basic than the foregoing. It consists essentially of hornblende, with a variable proportion of felspar and sometimes a little biotite; garnets are often present but their distribution is not uniform. This type is usually finer-grained than the grey gneiss and its banding is less conspicuous. Coarse-grained types occur, however,

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sometimes approaching a pegmatite. The black hornblende-schist is widely distributed. It is intercalated in the grey gneiss in thin streaks and lenticles, and in continuous bands, often of considerable breadth. Occasionally the bands of black hornblende-schist are transgressive to the grey gneiss.

(3) The granite-gneiss is not always easily distinguishable from the grey gneiss, except where it has a pink or red colour. Typically it is a quartz-felspar-rock with little hornblende, and it is usually finer-grained than the grey gneiss and less conspicuously banded. It has been recorded only from the central and eastern portions of the island.

Pegmatite.—Coarse felspathic pegmatites, often very thick, are common. Two varieties are recognisable, one pink and the other grey. The former is possibly connected with intrusions of granite-gneiss.

Paragneisses.—Mr. Eyles reports an isolated occurrence of rocks similar to those of Dun Gott.[1] They occur on the south-west side of Vaul Bay forming two skerries parallel with the shore. The larger skerry is 200 ft. wide and consists of rusty weathering pyritous calc-silicate-rock, biotite-garnet-schist and graphite-schist, with seams of magnesian marble. Mr. Bailey has also mapped a few feet of impure marble and calcareous schist, surrounded by granite-gneiss, in the extreme east of Tiree, on the coast just north of Eilean Liath; and Mr. Eyles a very small outcrop of similar rock surrounded by grey gneiss, at the south end of Loch Riaghain.

Garnet-Gneiss.—Mr. Simpson records two bands of garnet-gneiss which is probably paragneiss. The largest is about a quarter of a mile in breadth and occurs at the south end of Hynish Bay. It varies from coarse garnetiferous biotite-gneiss to garnet-biotite-granulite. A second band occupies a narrow strip of country stretching from the west side of Loch a' Phuill to Moss. Mr. MacGregor reports a further exposure of similar rocks just west of Loch Bhasapoll. In association with the Loch a' Phuill outcrop, Mr. Simpson found a strip of rock rich in magnetite (*see* p. 105). This grades from an almost pure magnetite rock into garnet-biotite-gneiss.

Tiree Marble.—Marble from Tiree, apart from the thin seams mentioned above, has long been well known. A. K. Coomaraswamy has described the chief occurrences in considerable detail.[2] Two varieties are found, distinguishable macroscopically by their colour. The pink "coccolite" marble, so familiar in museums, occurs in considerably less bulk than the greyish white type, which is also pyroxene-bearing. All previously described localities for both types are in the neighbourhood of Balephetrish Hill; Mr. MacGregor records an additional small exposure of the pink type about 5 miles away on the west coast

[1] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 104.
[2] *Quart. Journ. Geol. Soc.*, vol. lix, 1903, p. 91 *et seq.*

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between the north-east end of Eilean Ghreasamuill and the mainland.

The marbles of the Balephetrish district are of unusual interest, both in regard to their texture, and to their field relationships.

Good contacts of marble and gneiss may be seen, both in the quarry on the west side of Balephetrish Hill, and on the shore to the west. In each of these localities Mr. Bailey and Mr. Eyles found that relations of the marble to the gneiss surrounding it are those of an intrusive rock. In the quarry, the pink marble is seen to cut sharply across lines of movement and flinty crush-bands in the gneiss, while on the shore the marble trangresses crushed and folded gneiss, and includes fragments of material which in some cases can be matched in the neighbouring orthogneiss. On the south end of the shore exposure a conspicuous crush-line occurs in the orthogneiss bordered by thick lines of black flinty crush-rock. The marble seems to have extended a tongue along this dislocation and a renewal of crushing has involved this tongue, with the development of a flinty textured grey limestone crush-rock (Coomaraswamy's mylonized limestone).

Flinty Crush-Rock.—Veins and bands of black, or occasionally green and epidotic, flinty crush-rock are common in Tiree, west of Gott Bay, and are more numerous than those described from Coll last year.[1] Mr. MacGregor records that in the north-west end of the island a crush-belt, some 150 yards broad, crosses from coast to coast in a north-easterly direction from a point 300 yards south-east of Eilean Ghreasamuill on the west to Rudha Port Bhiosd on the north. The strike of the gneiss on the two sides of this belt becomes markedly discordant near the north coast.

PRE-MESOZOIC ROCKS: ARDNAMURCHAN

The chief points of interest noted are:—

(1) *Moine Gneisses.*—The survey of the area of gneiss to the east of the Tertiary volcanics and plutonics, and west of the Ockle and Glenmore Rivers, has now been completed by Mr. Simpson. He finds that the gneiss is of a flaggy psammitic type with pebble-bands and subordinate mica-schist, that is nearly always garnetiferous.

North of Kentra Bay, Mr. Eyles has traced the Carna Pelitic ('Summary of Progress for 1921,' pp. 89, 90), and the psammitic belt to the east of it, through Eilean Shona to the north shore of North Channel, Loch Moidart.

Towards the western margin of the Carna pelitic belt, thin pale-coloured garnet-zoisite seams have been noted, whilst the width of the outcrop has diminished from 1½ miles at Carn Mor to about three quarters of a mile at North Channel.

East of the psammitic belt, a minor band of garnetiferous pelitic and semi-pelitic gneiss has been mapped; it is succeeded to

[1] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 95.

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the east by another belt of psammitic gneiss. The presence in it, in the Moidart area, of numerous thin garnetiferous seams, resembling the garnet-zoisite seams of the Carna Pelitic, distinguishes this psammitic belt from that immediately to the east of the Carna Pelitic.

(2) *Lamprophyres.*—Lamprophyre dykes and sheets have been mapped in great numbers by Messrs. Eyles and MacGregor. They do not occur west of a line joining Glenmore River on Loch Sunart with Gortenfearn on the north side of the peninsula. Both foliated and non-foliated types occur, and the latter, near Loch Sunart, have been involved in obvious folding.

Camptonites.—Two additional occurrences of camptonite dykes ('Summary of Progress for 1921,' pp. 96, 104) have been noted by Mr. Simpson in Tiree, and others by Messrs. Eyles and MacGregor in Ardnamurchan. In this latter district camptonites do not occur west of a line joining Hacarsaid on the north coast and Dun Ghallain on Loch Sunart, whereas east of this line they are frequent.

The Tiree examples run W.N.W. and N.W.; and on the mainland, of 49 camptonites, 43 have directions between W. and N.N.W., and of these 26 trend between W.N.W. and W. by N.

Mr. Eyles has mapped an E.–W. dyke of unusual interest at the middle of the west of the island of Riska, Loch Moidart. It shows three continuous portions.

(*a*) The most northerly portion—4 ft. thick—consists of numerous ovoid cores of a greenish crystalline aggregate, most probably serpentinised olivine, with occasional crystals of a light brown mica like phlogopite, set in confluent sheaths of black, platy matrix.

(*b*) The middle portion consists of decayed basic igneous rocks too rotten to determine, and is about two feet across.

(*c*) The third portion is a slightly ocellar camptonite about two feet across.

The relations of the three portions are somewhat obscure, but are probably those of a composite dyke. The sheath-and-core structure is different from that occurring commonly in pitchstone, as the sheaths do not correspond in composition with the cores. Mr. Bailey last year found a sheath-and-core dyke of the Riska type east of the river mouth at Camas an Lighe, four miles farther south-west. The sheaths proved on slicing to be camptonite, and the cores decomposed olivine-nodules.

Mr. Eyles describes a small, but well exposed, volcanic vent in the south coast of Eilean Shona, Loch Moidart, about half way between Arean and Eilean Shona house. The vent, which penetrates Moine gneiss, is filled with angular, sub-angular, and rounded blocks, up to two feet in length, set in fine-grained tuff. The blocks are all of local types of gneiss and dykes with the

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exception of a number of brown calcareous nodules, pale grey on a freshly broken surface. One of these proved to be an olivine nodule very largely replaced by carbonates. A few crystals of chrome-spinel and a second ferro-magnesian mineral were observed. The original structure of the serpentinised olivine is retained.

TRIAS AND JURASSIC: ARDNAMURCHAN

In the neighbourhood of Kilchoan, Dr. G. W. Lee has confirmed Professor Judd's recognition of the Trias and of all the divisions of the Jurassic, excepting the Rhaetic, up to and including the Inferior Oolite. The basal beds of the Jurassic (Infra-lias of Judd) were specially searched for Rhaetic fossils but without result. The Great Estuarine Series is believed by Dr. Lee to be represented by certain fissile shales containing *Estheria murchisoniæ*, a fossil characteristic of this horizon in Skye. The only exposure of these beds occurs in the sea cliff at Sron Bheag, one mile S.W. of Kilchoan Bay, where it is separated from neighbouring outcrops of the Inferior Oolite by intrusions, and probably also by faults.

Mesozoic sediments have been preserved under a cap of Tertiary basalt lavas N. of Ardslignish.

On the scarp south of Lochan a' Mhadaidh Riabhach a compact limestone, which may be 25 feet thick, is seen. It is crowded with *Gryphaea arcuata* and other fossils and is of Lower Lias (Sinemurian) age. Traced eastwards along the scarp the limestone rapidly thins out. From where the limestone disappears a thin sandstone is traceable at intervals round the scarp. A good section of this sandstone seen in a small stream which enters Loch Sunart at Camas Fearna below the base of the lava is, 3 feet mudstone, 2 feet gritty conglomeratic sandstone, 3 feet conglomerate, resting on gneiss.

The conglomerate consists of well-rounded pebbles of quartz and a few angular pieces of gneiss. The matrix is grey-green and contains occasional rounded grains. The conglomerate grades up into a conglomeratic sandstone not more than five or six feet thick.

The precise geological horizon of the sandstone is uncertain; it is nowhere seen in connection with the Lias Limestone; it does not possess a markedly calcareous matrix, nor does it show the cornstone concretions often characterising the Triassic deposits of the district; and it lacks the flint pebbles and wind-rounded grains often met with in the Tertiary sandstones of Mull and Morven.

TERTIARY COAL: ARDNAMURCHAN

In the winter of 1921 a seam of coal was uncovered by a local resident, and was widely reported upon in Scottish newspapers. The outcrop of coal occurs 550 feet above sea-level, in a small stream which falls into the sea at Camas Fearna, Loch

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Sunart. The coal is from 1½ to 2 feet thick with 2 to 4 in. sandy fireclay below, resting on gneiss. It is a brown coal of poor quality, well-bedded and clean in one part of the section; but elsewhere it contains a large admixture of grit, and occasional flints. The sandy material in the coal consists of beautifully rounded quartz-grains. Above the coal are about four feet of volcanic mudstone, which contains well rounded grains of quartz in its lower portion.

A search for fossils in the confused upper portion of the coal deposit yielded to Mr. Simpson a shark's tooth, which Dr. Smith Woodward has identified as belonging to the genus *Oxyrhina*, and probably *O. mantelli*, a species of late Cretaceous or early Tertiary age. The coal is absent in stream sections on either side, so that its extent appears to be very limited.

CRETACEOUS AND TERTIARY SEDIMENTS : MORVEN

In the 'Summary of Progress for 1920' (p. 36), Mr. Bailey claimed that the Chalk of Western Mull had been exposed to desert conditions soon after its elevation. It was first weathered; then its crannies were filled with quartz-sand characterised by wind-rounded grains; finally it was silicified; and the associated sand was enclosed in a chert matrix. This took place before the advent of the warm temperate climate which witnessed the outbreak of vulcanicity in the district.

Last season, Mr. Bailey visited Loch Aline in Morven, to investigate the well-known white sandstone there exposed above the Cenomanian Greensand. He found a fair proportion of wind-rounded grains in this sandstone. In Western Mull, the similarly placed sandstone at Gribun underlies silicified Chalk, and is therefore clearly of Cretaceous date. It, too, contains apparently wind-rounded grains, but its texture is finer than that of the Loch Aline sandstone, so that a close comparison is impossible.

Under these circumstances, Dr. Lee advised a visit by Mr. Simpson and Mr. Manson to the outlier of Beinn Iadain, north-west of Loch Aline. They obtained the following succession at a point spoken of by Prof. Judd as the south-east angle of Beinn-y-Hattan :—

	Ft.	in.
Mudstone	1	6
Sandstone with streaks of lignite	2	0
Sandstone (round grains) reddish brown passing down to white; occasional plant fragments	1	9
Lignite streak	—	—
Hard white fireclay, full of roots	0	4
Lignite with rounded sand-grains	0	2
Silicified chalk with flints (Senonian)	2	6
Sandstone: glauconitic, with shell fragments in upper part, but in the main white and unfossiliferous. Most of the grains are beautifully rounded and polished, averaging 0·4 mm., but often as little as 0·2 mm. in diameter. The rounding surpasses that met with in grains of comparable size collected from the modern desert near Giza Pyramids	25	0

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	Ft.	in.
Hard calcareous sandstone, grains well-rounded; a few marine shell fragments	1	6
Soft pale-brown sandstone, some grains rounded; a few marine shell fragments	2	6
Exogyra conica Greensand (Cenomanian), quartz-grains small, but some show rounding.		

From analogy with the Beinn Iadain section the round grains of the Loch Aline Sandstone do not exclude the Upper Cretaceous date assigned to this sandstone by Prof. Judd. The millet-seed sandstone between the Senonian Chalk and Cenomanian Greensand of Beinn Iadain cannot be exactly dated, but Prof. Judd has recorded *Belemnitella mucronata* from the Chalk.

Mr. Bailey claims that the Beinn Iadain evidence shows that the desert climate, which persisted for some little time after the elevation of the Chalk, had long previously affected the continent bordering the Chalk sea; and that the sands above the Cenomanian Greensand in Morven and Mull were blown into the Chalk sea from a neighbouring desert. Mr. Hume's account of the similarly placed sands of Antrim supports this hypothesis. Moreover, in the literature of chalk residues from the Franco-British area, there are many references to rounded quartz-grains of small size. Accordingly, the suggestion is advanced that the relative absence of river-borne contamination in the European Chalk is in large measure due to a desert climate affecting the neighbouring continents.

TERTIARY IGNEOUS COMPLEX: ARDNAMURCHAN

The investigation of the plutonic complex and the surrounding rocks at the west end of Ardnamurchan has been continued by Mr. Richey. Mr. Simpson has mapped the less complicated country east of Ben Hiant.

Tertiary Lavas.—The Tertiary lavas surveyed by Mr. Simpson form a faulted outlier to the east of Ben Hiant. They cover an area of about 2½ square miles, and are separated from lavas bordering the vent complex of Ben Hiant by a N.N.W. fault which skirts the west side of the peninsula of Ardslignish, and runs up the hollow towards Loch Mudle, throwing down the lavas to the east. The southern portion of the lavas forming the promontory at Ardslignish is also a faulted block, let down some 200 feet to the south by an east-and-west fault parallel to, and on the southern edge of, the public road where it crosses the peninsula.

The group, as preserved, is about 300 feet in thickness, and where seen, the basal member is nearly always found to rest on brown volcanic mudstone usually containing some rounded sand grains. The lavas are medium or fine-grained olivine-basalts, the olivine forming small but conspicuous phenocrysts. The individual flows may occasionally be rudely columnar, and have well-marked amygdaloidal upper portions overlain by conspicuous red boles.

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Segregation veins have been noted at various localities. The lava flows dip at a low angle to the south of west. In the Kilchoan district, farther west, only small remnants of Tertiary lavas are preserved overlying the Mesozoic and pre-Mesozoic sediments.

Agglomerate Vents. Part of the well-known Ben Hiant vent was described in last year's "Summary." It forms one of a series which extends across the peninsula on the east of the plutonic complex. Only a part of this area has yet been mapped, but the agglomerates are known to be much invaded by minor intrusions including cone-sheets. Agglomerate free from cone-sheets outcrops along the east side of a promontory bounding the eastern side of Kilchoan Bay. These cone-sheets and the amygdaloidal basalt lavas cut by them are much shattered by explosions along the edge of the vent, and pass gradually into true agglomerate, which contains fragments of both, and also blocks of Mesozoic and pre-Mesozoic sediments.

Structural Features in country bordering Plutonic Complex. A general inclination away from the plutonic mass, usually at about 30°, is a feature of the sediments bordering it (Fig. 6). The simple dome structure thus indicated is complicated by faults near which variations from the general dip are found. Two curving faults, for example, have let down a strip of basalt lavas eastwards of Kilchoan Bay. The more easterly fault where seen on the shore is evidently later than the cone-sheets which there cut pre-Mesozoic grits. Perhaps the faulting is earlier than the dome, the formation of which appears connected with the intrusion of the plutonic masses. The junction between the gabbro intrusion and Lower Lias shales is well seen on the coast about 3 miles west of Kilchoan Bay. The shales dip southwards at 30° and form a roof to the intrusion, the plane of contact being parallel to the bedding. A similar relation is seen at the extreme westerly point of the peninsula, where a remnant of roof composed of shales dipping west is exposed at the top of the coastal cliff. North of Kilchoan Bay, however, the junction between the outermost gabbro and the country rocks can be followed down a steep hill-side, and is evidently highly inclined or vertical. It is possible that a doming of the roof has led to a dragging up of the walls.

Sills. In the Kilchoan district, quartz-dolerite sills are abundant in the Mesozoic and pre-Mesozoic bedded rocks. They are usually thin and are always fine-grained. In microscopic slices they are variolitic and resemble the Sgurr Dearg type of variolite from Mull. They are sometimes composite, with basic margins and acid centres, and resemble the composite sills of Skye and Mull in that the acid magma has followed the basic before complete consolidation. A good example may be seen on the shore just west of Kilchoan pier. The sills as a group are earlier than the cone-sheets, by which they are invariably cut.

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Cone-Sheets. The remnants of a circular belt of cone-sheets[1] (quartz-dolerites of Talaidh type) which has been broken through by plutonic masses is shown on the sketch map (Fig. 6). A later system of sheets which cut the plutonic intrusions has been

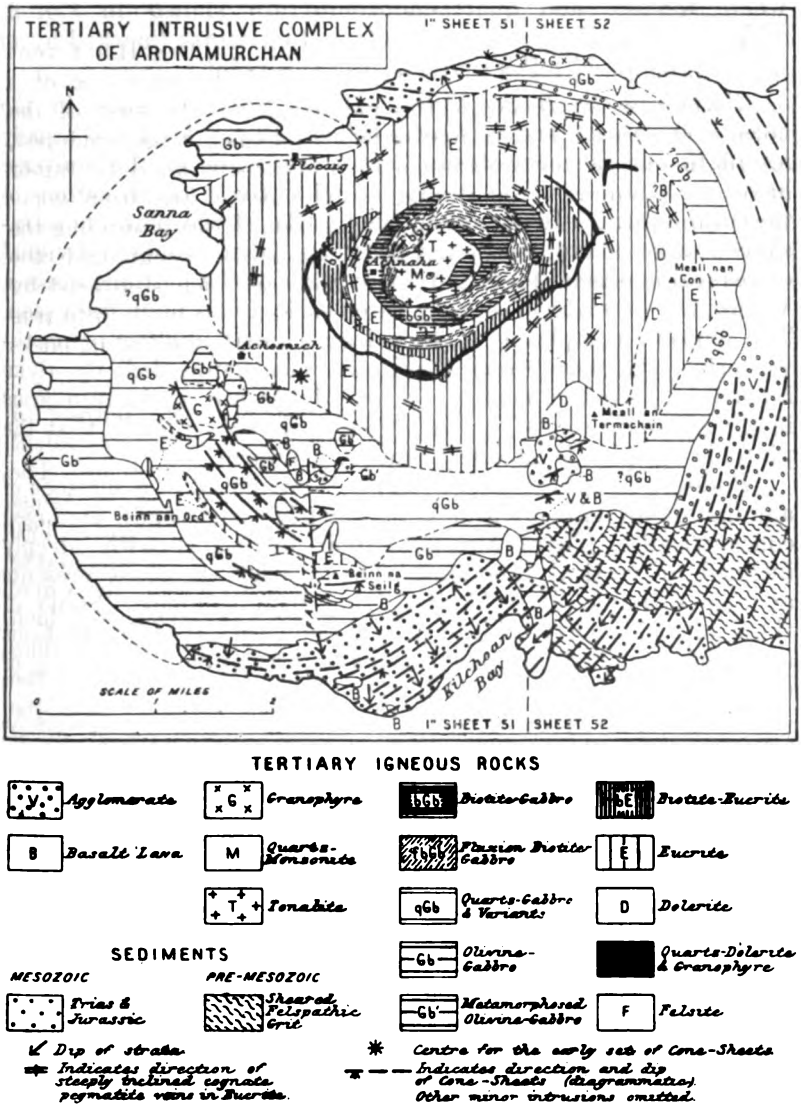

FIG. 6.—*Tertiary Intrusive Complex of Ardnamurchan.*

mapped in the south-west sector where they are fairly abundant. They differ from the Talaidh cone-sheets in being freely porphyritic and appear to be more basic. They are usually inclined at angles of 60 to 70 degrees, whereas the dip of the Talaidh cone-sheets is usually lower than 45°. The later sheets are considered

[1] 'Summary of Progress for 1920' (*Mem. Geol. Surv.*), 1921, p. 42.

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to be a partially developed system. The investigation of the relations of the two sets of cone-sheets has not been completed, but north of Kilchoan Bay, the directions of the two sets differ : the later group would appear to belong to the plutonic centre where tonalite and quartz-monzonite are shown in Fig. 6; while the Talaidh cone-sheets conform to a centre (marked by an asterisk) about 1½ miles south-west of this point.

North-westerly Basic Dykes.—Dykes are numerous in the coast section east and west of Kilchoan Bay. They are usually found to cut the cone-sheets, but a few cases of the converse have been noted. The group is evidently a continuation of the Mull swarm. In direction, they strike at the plutonic intrusions that lie inland, yet do not penetrate them, though individual dykes can be traced to within a few yards of the plutonic masses. Within the plutonic mass, only three basic dykes have been seen. The plutonic complex is traversed by a great number of north-westerly crush-lines, but these are unaccompanied by dyke intrusions. On the northern coast, dykes are again numerous in the Mesozoic strata east of Plocaig. It seems likely that the plutonic complex is later than the dyke swarm.

Plutonic Complex.—The complex is composed of a number of annular or arcuate intrusions, or intrusive complexes, arranged concentrically. There are individual intrusions with steeply inclined or vertical junctions. The district therefore presents another example of a Tertiary ring-dyke complex. Some of these intrusions have chilled margins but usually their junctions are quite unchilled, and may be masked by apparent grading of one type of rock into its neighbour.

The complex may be subdivided for descriptive purposes as follows :—

(1) Olivine-Gabbro.
(2) Quartz-Gabbro Complex.
(3) The Great Ring of Eucrite.
(4) The Central Complex.

The majority of the ring-intrusions, (3), (4) and part of (2) conform to a centre east of Achnaha, where tonalite and quartz-monzonite have been mapped. Others, (1) and part of (2), in the south-west sector, appear to have reference to the earlier intrusion-centre about which the Talaidh cone-sheets are arranged. There is considerable evidence that the ring-dykes of the Achnaha centre are a later group than the others, and that, of this group, the central members succeeded the peripheral.

Different types of scenery characterise the several belts of country occupied by the above rock-assemblages. The Great Ring of Eucrite forms high rocky ground in striking contrast to the lower-lying, grass-covered area occupied by quartz-gabbro immediately outside it. The inner side of the Eucrite-ring constitutes an amphitheatre of crags up to 400 ft. high, within which the rocks of the Central Complex form relatively low

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ground, with curving ridges and hollows that mark the course of the various intrusions composing it.

(1) *Olivine-Gabbro.* This perhaps is a single intrusion related to the early centre marked by an asterisk on the map (p. 99). In the northerly part of its southern limb, it possesses a well-marked fluxion-banding, usually inclined northwards at angles of from 35 to 65 degrees. Strips of fine-grained basic rock arranged parallel to the banding are a feature of this part of the intrusion. They are evidently xenoliths, perhaps cognate to the gabbro, and not intrusions cutting it. The gabbro becomes very fine-grained towards its outer margin. An isolated mass of olivine-gabbro north-east of Sanna Bay may perhaps be a portion of this intrusion. It also is characterised by a fine grain on its outer northern side as well as towards its inner margin against eucrite.

(2) *Quartz-Gabbro Complex.* The rock-types mapped together as quartz-gabbro show considerable variation in composition, due perhaps to absorption of more basic material; many isolated basic masses have been mapped in the south-west sector of the complex. The quartz-gabbro there has a well-developed acid mesostasis, which projects on weathered rock-surfaces as whitish patches. In the eastern sector the quartz-gabbro appears in the field to be uniformly crystalline. In the south-west sector the outermost quartz-gabbro intrusion is chilled to a fine-grained porphyritic rock along its outer boundary. Aplitic veins from it abundantly cut the olivine-gabbro in contact, giving rise to a belt of 'intrusion-breccia,' which varies in width from a few feet to a hundred yards and more. On the inner side of this quartz-gabbro, where it is in contact with a strip of eucrite, it is quite coarse-grained and has evidently extensively corroded the eucrite. The latter occurs as a vertical screen forming the backbone of the Beinn nan Ord ridge. It there separates the outer quartz-gabbro from an inner quartz-gabbro which is chilled against it (and appears to be highly baked). The screen, when traced downhill at the north end of Beinn nan Ord, disappears, and is replaced by hybrid quartz-gabbro, which forms a ridge at a lower level extending northwards towards Sanna Bay. It likewise disappears in a valley separating the south-east end of Beinn nan Ord from the west slopes of Beinn na Seilg; but is found again on higher ground opposite, and continues from there to a northern summit of the latter hill.

North-east of Beinn nan Ord, some isolated masses of highly metamorphosed olivine-gabbro, lettered Gb^1 (Fig. 6), have been mapped. This rock is characterised in the field by its dead-black colour. Under the microscope its felspars are seen to be clouded with dark inclusions. In some sections, its constituent felspar, augite and olivine, are found to have crystallised simultaneously in eutectic fashion. At contacts the rock is usually corroded by the quartz-gabbro, and the latter is

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contaminated with basic material. The masses formed of this rock-type are probably the remnants of a ring-intrusion, isolated by the later quartz-gabbro; part of its inner margin still remains in relation to agglomerate and compact basalt-lava. The outline of this inner margin indicates that the metamorphosed gabbro formed a ring-intrusion related to the early intrusion-centre about which the Talaidh cone-sheets are arranged.

A small mass of granophyre mapped to the north of Beinn nan Ord may be mentioned. It sometimes becomes more basic towards its junction with surrounding quartz-gabbro. The latter is cut by granophyre apophyses, and the granophyre is presumably a late differentiate of the quartz-gabbro magma.

A mass of agglomerate and basalt lava occurs north-north-east of Kilchoan Bay, on the south side of Meall an Tarmachain; on its west and south sides, this mass forms a roof to the quartz-gabbro intrusion, and slopes gently southwards. On its north side it is vertically cut across by the margin of the Great Ring of Eucrite.

On the north side of the peninsula a good many Talaidh cone-sheets cut the quartz-gabbro, and are very abundant in the Mesozoic strata hard by. They fail to penetrate the eucrite mass whose outer margin obliquely crosses their direction. There is thus some evidence of the quartz-gabbro having preceded the intrusion of the eucrite ring.

(3) *The Great Ring of Eucrite.*—This rock is always coarsely crystalline, and olivine is usually a conspicuous mineral. The relative amount of olivine and augite varies very considerably, and frequently one mineral is developed to the practical exclusion of the other. The felspar is either bytownite or anorthite. In the eastern sector an outer mass of eucrite grades into highly baked dolerite against which, along a vertical junction, an inner eucrite is appreciably chilled. The dolerite occurs on the adjoining hills of Meall nan Con and Meall an Tarmachain, but it is absent in the valley between.

A feature of the eucrite mass as a whole is a development of thin cognate pegmatite veins. They often follow a straight course (in the eucrite) extending for many yards, and are vertical or steeply inclined. At any particular locality these regular veins are very closely parallel; they change direction from place to place, so as to run everywhere parallel to the margins of the ring-intrusion. They are sometimes multiple with borders rich in augite, and felspathic centres, or vice-versa.

The normal eucrite frequently contains patches of very coarsely crystallised gabbro or eucrite, which are sometimes in continuity with the pegmatite veins. The veins are considered to have been formed late in the consolidation of the eucrite mass, and to represent contraction cracks into which residual magma found its way. The parallelism in direction between the regular system of veins and the margins of

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the ring-intrusion is so striking that it seems reasonable to accept the vertical or steep inclination of the veins as evidence of the essentially dyke-like form of the whole intrusion.

(4) *The Central Complex.*—This is composed of a number of ring-intrusions. Its various rock-types, except the quartz-dolerite ring dyke, are characterised by containing biotite. The amount of biotite varies according to the acidity of the rock. It is very rarely seen in normal eucrite, and in biotite-eucrite it is rather scarce. In biotite-gabbro the mineral is plentiful, while in tonalite and quartz-monzonite it is abundant.

Quartz-Dolerite and Granophyre Ring-dyke.—This narrow dyke, about 30 yds. wide, outcrops at the foot of the amphitheatre of eucrite crags already described. It has been intruded approximately along the inner margin of the Great Ring of Eucrite, but deviates a little on either side of this line. It consists of quartz-dolerite reticulately veined by granophyre or felsite. Outcrops are abundant but marginal exposures are few. At the east side of the Central Complex, however, the quartz-dolerite is seen chilled against eucrite on its outer margin, and the junction is inclined eastwards, *i.e.*, outwards, at about 70 degrees. A little north of this, close to its northern termination, the dyke is only 3 ft. wide, and is replaced a few yards farther north by a gabbro or eucrite breccia strung with granophyre veins. This narrow dyke of intrusion-breccia has clean-cut junctions with solid eucrite on either side; and its walls are inclined north-eastwards, *i.e.*, outwards at 70 degrees.

Biotite-Eucrite.—The rock is typically a felspathic eucrite containing scattered flakes of biotite. It weathers comparatively easily and may thus be distinguished in field exposures from eucrite proper, with which it is in contact. A sharp junction has been noted between the two types of eucrite where the boundary line between biotite-eucrite and the inner narrow eucrite ring-intrusion crosses a track leading from Achnaha and Plocaig.

The Inner Ring of Eucrite.—This eucrite generally gives rise to a low ridge. It everywhere carries cognate pegmatite-veins, with conformable strike and steep inclination.

Fluxion Biotite-Gabbro of Sithean Mor.—The rock-type is a medium-grained, dark gabbro, with well-formed felspars arranged parallel to one another. Biotite is usually fairly plentiful. An intrusion of this rock-type forms the curving steep-sided ridge of Sithean Mor at the south side of the Central Complex. In the south half of the ridge, the fluxion gabbro is interbanded with a more felspathic coarse-grained gabbro. The bands are vertical or steeply inclined. They conform in direction to the changing course of the northern

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steep slope of the ridge, which agrees closely with the inner margin of the intrusion. On the south side of the ridge coarse biotite-gabbro and eucrite, which is mapped as part of the Great Ring, are cut by a dyke-like irregular intrusion of basic rock containing biotite. The intrusion has chilled edges and appears to be an offshoot from the fluxion biotite-gabbro; its occurrence at any rate indicates that the biotite-bearing rock series of the Central Complex is of later origin than the biotite-free eucrite of the Great Ring.

The Glendrian Ring-dyke of Fluxion Biotite-Gabbro.—The course of this intrusion is marked by a conspicuous ridge encircling an area occupied chiefly by tonalite. The intrusion forms a complete ring, except for an interruption near Achnaha, where it is broken through by the later intrusion of tonalite. The rock is often fissile, owing to its very perfect fluxion-structure, which was frequently noted to be parallel to the direction of the ring-dyke, and to be steeply inclined. The margins of the intrusion are unchilled. A sharp junction with biotite-gabbro outside it is well-exposed along its south side.

Biotite-Gabbro.—This type is very coarsely crystallised, with biotite plentiful. Quartz is often seen in hand specimens while olivine is absent or scarce. Large irregular crystals of iron-ore are usually plentiful. The detached areas formed of biotite-gabbro as shown on the map, appear to be portions of one ring-intrusion separated by the latter Glendrian Ring-dyke of fluxion biotite-gabbro. An unchilled contact between the latter and one of the outer portions has been already mentioned. No actual contacts with the Inner Ring of Eucrite, which encloses it, have been observed. Their distinctness seems to be clearly established west of Achnaha, where the Inner Ring of Eucrite forms a little ridge, along the eastern side of which it becomes finer grained, next to outcrops of very coarse biotite-gabbro.

Tonalite.—This mass is fairly uniform in composition, and becomes progressively finer-grained towards its outer margin; numerous acid apophyses occur in the surrounding gabbros. An elongate strip of gabbro, probably a " screen," occurs in the south-east part of the mass : on its outer side tonalite is chilled in contact with it.

Quartz-Monzonite.—A small eminence rises in the centre of the peat-covered ground occupied by the intrusion just described. Its summit is composed of a small mass of quartz-monzonite which presents a sharp, slightly-chilled, margin against the tonalite surrounding it. Its outcrop, as will be seen on the map, is elongated in the same north-easterly direction as the tonalite and gabbro rings by which it is surrounded.

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Glaciation: Tiree and Ardnamurchan

Tiree. On Ben Hynish, at the south-west end of Tiree, Mr. Simpson has observed numerous striae pointing N. 20° W. and N. 30–35° W. The ice-movement was probably from south-east since in Iona and Coll the striae are directed N.W.

Kentra Glacial Fan: Ardnamurchan. East of Kentra Bay, a large peat moss extends 2 miles from north to south and 1½ miles from east to west. Sand and gravel underlie the thick peat, and are well stratified in a section 650 yds. W. of Shiel Bridge, where 11 ft. of sand and gravel may be seen under 4 ft. of peat.

South of the River Shiel the eastern limit of the gravel lies between Acharacle School and New Shiel Bridge, and forms a very irregular eastward-facing scarp, 10 to 15 feet high. Two or three small discontinuous eskers lie just east of this scarp, one of them being confluent with the gravel spread. The hollow which contains the eskers falls gently eastwards to merge with a broad alluvial flat bordering Loch Shiel. These Kentra gravels apparently represent a large glacial outwash-fan; while the scarp marks the former margin of a glacier occupying Loch Shiel; and the gravel-eskers, the courses of subglacial streams. Near the eskers, a small kettle hole occurs in low-lying gravel. The question arises whether this spread of gravel was laid down in a shallow sea and sorted by the waves, or was deposited on a land surface by glacial streams. The ground has a gentle slope and the Kentra gravels thin out from east to west, until a faintly marked raised-beach bluff is encountered a few feet above high-water mark. In the scarp the gravel reaches a height of 60 feet above O.D., while at Kentra, rather more than a mile away, its surface is only 16 feet above O.D. On this evidence it seems clear that the gravel accumulated on dry land. Mr. Bailey, who has seen both localities, states that the Kentra fan and eskers reproduce on a larger scale the phenomena occurring at the mouth of Glen Forsa, Mull.[1]

Economics: Tiree and Morven

Two items of economic interest were investigated in the course of last season's field work.

(1) *Magnetite, Tiree.* Mr. Simpson has mapped a deposit of magnetite at the north-west corner of Loch a' Phuill, immediately east of a stone fence which runs N.N.E., parallel to, and about 80 yards away from, the shore of the loch. The magnetite is in the form of a band striking N.N.E. in conformity with the bordering gneiss, and is visible for about 150 yards before it disappears under surface deposits.

The band is about 13 feet in breadth, and the middle seven feet appear to be fairly pure, but towards the edges

[1] 'Summary of Progress for 1909' (*Mem. Geol. Surv.*), 1910, p. 37.

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the magnetite is interfoliated with quartz and garnet to a notable extent.

A sample from the middle portion has been analysed by Mr. Sutcliffe and has been found to contain only 27·93 per cent. iron.

(2) *Glass-sand.* A friable white sandstone, 20 feet thick, adjoins the road neighbouring Loch Aline for about a mile and a quarter north-east from the village. It generally outcrops towards the foot of a steep escarpment. Its immediate roof is furnished by a few feet of mudstone, but above this comes basalt lavas which would allow of easy mining of the sandstone. The loch affords opportunities for shipping at any tide and almost any weather. Mr. Bailey has had a specimen analysed, with the following result :—SiO_2 99·69; Fe_2O_3 0·02 per cent.

4. North Highland District

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Field work was carried on during the summer in one-inch Sheets 102, 108 and 103. The unsurveyed area between Lubcroy and Corriemulzie in the south-west of Sheet 102 was mapped and a re-examination made of part of the igneous complex of Sgonnan Beag. This Sheet is now completed. A considerable area in the south-central and central parts of Sheet 108 was surveyed, and in addition a rapid revision made of nearly half of Sheet 103, with the object of preparing a new colour-printed edition of this map showing the " drift " geology in addition to the " solid."

Sutherlandshire

One-inch Sheet 102 (Lairg Sheet)

In the Corriemulzie district to the south-west of Oykell Bridge (Sheet 102), Messrs. Haldane and Ross report the occurrence of a broad area of garnetiferous mica-schist extending northwards for about four and a half miles from the south margin of the Sheet and forming a continuation of the pelitic belt mapped in the north-west of Sheet 93.[1]

The rock is a medium-grained corrugated muscovite-biotite-schist, generally with abundant garnets. On the western margin the prevailing dip is to the east or south-east at moderate angles, but there is considerable local variation and contortion. The junction of these pelitic rocks with the siliceous granulites

[1] 'The Geology of Ben Wyvis,' etc., Explanation of Sheet 93 (*Mem. Geol. Surv.*), 1912, p. 31.

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to the west is generally marked by extreme interfolding, but their northern edge is sharp, and defined, at least locally, by a fault line. The north-eastern margin between Creag Loisgte and Cnoc nam Bad Bog is much-folded with prevalent south-west dip. The remainder of the area northwards to Lubcroy is occupied by siliceous or banded siliceous and semi-pelitic granulites, often rodded and containing narrow belts of garnetiferous mica-schist.

The area between the Sgonnan Beag and the Moine thrusts has been revised by Mr. Phemister. He finds that, though the structure is complicated by an abundance of minor thrusts, the igneous intrusion in this area appears to be of a laccolithic nature and in all likelihood forms part of the Cnoc na Sroine magma. Its base probably rests on the Pipe Rock and its roof is formed, sometimes at least, by the Durness Limestone. Inclusions of the Limestone, Serpulite Grit, Fucoid Beds, and Quartzite are found within the igneous rock, at one locality in their proper stratigraphical sequence.

The igneous rocks can be divided into two main portions, an upper alkaline part (syenite), occupying by far the larger superficial area, and a lower ultra-basic part of variable composition. The syenite is mostly soda-felspar with varying accessory minerals, including garnet and riebeckite. Borolanite in the restricted application of the term suggested by Dr. Shand[1] has not been met, but a felspar-melanite rock which would be included under the term "borolanite" as used by Drs. Horne and Teall,[2] has been collected from several localities where it is associated with limestone, in one case very intimately.

At many places basic "knots" are found in the syenite, the most instructive locality being the Oykell River just below its junction with the Allt Sail Ruathair, where the following downward succession is found, (*a*) syenite, (*b*) syenite with basic knots, (*c*) basic rock with syenite veins, (*d*) basic rock with fewer veins of syenite and enclosing ultrabasic patches. A further downward succession may be seen in exposures on a small hill in the north-eastern corner of the area at the headwaters of the Amhainn Gleann na Muic, where basic rock veined by syenite rests on an ultrabasic mass with diorite veins.

One-inch Sheet 108. (Altnaharra Sheet)

Mr. Wilson mapped the ground around the Fiag River between Loch Shin and Ben Hee. He reports that this area is almost entirely occupied by normal siliceous granulites with a general dip to the N.E. at about 45°. In one of the small streams which flow into the Fiag River from the east a thin band of calcareous rock was noticed, and on microscopic examination found to contain brucite.

[1] S. J. Shand, 'On Borolanite and its Associates in Assynt,' *Trans. Edin. Geol. Soc.*, vol. ix, 1910, p. 415.

[2] J. Horne and J. J. H. Teall, 'On Borolanite,' *Trans. Royal Soc. Edin.*, vol. xxxvii, 1895, pp. 163–178.

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The area surveyed by Messrs. Ross and Phemister to the west of the Lairg-Altnaharra road includes the ground round Loch Ben Harrald and An Glas-loch and extends westwards for several miles. The prevailing rock is a rather coarse quartzo-felspathic granulite, grey or pinkish in colour and generally massive. The prevalent dip is east at angles of 25 to 40 degrees, and in this direction the rocks become more flaggy and micaceous layers more numerous. This banded type continues eastwards nearly to the Allt a' Ghlas-locha. Here Mr. Phemister finds that they pass beneath a series of granulites containing hornblende. These hornblendic rocks are undoubtedly an integral part of the schist series. In composition they vary from a black hornblende rock to a grey granulite speckled with radial aggregates of hornblende up to an inch in diameter. The conspicuous, often minute, banding due to alternate hornblendic and felspathic layers is very persistent, and some specimens recall the striped schists described by Mr. Read from the Allt Doire a' Chatha in Sheet 102[1]; other hand specimens resemble the hornblende-schists associated with the Shiness Limestone. Where seen in the Allt a' Ghlas-locha these hornblende-granulites have a persistent strike in a direction slightly E. of N., and appears to be sharply folded about an axis directed generally 5 to 15 degrees E. of S. and pitching to the S. The series of banded siliceous and biotite schists which underlies them to the west reappears east of the Allt a' Ghlas-locha with a dominant westerly dip. This suggests that the hornblende rocks occupy the core of a southward pitching synclinal fold. Somewhat similar types were found by Mr. Ross among the flaggy schists just north of the summit of Meall an Fhuarain where occasional thin layers are formed almost entirely of acicular hornblende.

The striped schists described above are immediately underlain in the Allt a' Ghlas-locha by quartz-felspar-granulites, and these overlie a broad belt of massive biotite-hornblende rocks or amphibolites. Two outcrops of similar rock were noted in a burn 650 yards E. 20°S. of the northern exit of An Ghlas-loch; one of these, 6½ feet thick, contains inclusions of different types of the granulites. Pyrites is abundantly scattered through it. The schists immediately below show much chlorite in papery laminæ. A sill-like intrusion of a coarse-grained faintly gneissose hornblende-felspar-rock, about 2 feet wide, was noted by Mr. Ross on the south-west slopes of Meall an Fhuarain. It occurs in a semi-pelitic band and is margined by a well-foliated gneiss with augen of pink felspar and streaks of granular quartz in a biotitic matrix.

A large proportion of the area surveyed in this Sheet is covered by morainic drift or peat. Mr. Wilson notes that on the south-west of Loch Shin, opposite the mouth of the Fiag River, the glacial striae show an east-and-west orientation indicating that

[1] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, pp. 101–102.

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the pressure of ice from the Ben More massif to the west was apparently sufficient to cause a deviation of the Loch Shin ice from its south-easterly course. Mr. Ross finds the average direction of striae on Creag Dubh Mhor and on the high ground west of the intake of An Ghlas-loch directed N. 31°E. thus betraying a general north-easterly movement during the period of maximum glaciation. Striae near the 1,100-ft. level indicate a somewhat later stage when the ice moved in a more easterly direction down the Allt an t-Sratha Dhuibh into the Mudale valley. Crescentic moraines are common along the course of the former, and a terminal moraine occurs a few hundred yards upstream from the junction with the Allt a' Ghlas-locha. The pass of Bealach na Creage Duibhe and the upper part of the valley of the Allt a' Ghlas-locha represent overflow channels draining north-eastwards from the low ground to the south.

One-inch Sheet 103. (*Golspie and Brora Sheet*)

The area revised by Mr. Read lies along the Fleet valley from the west margin of the Sheet to Aberscross, extending northwards nearly to the headwaters of the Brora and southwards to an east-and-west line through Loch Laoigh. The southern part of the Sheet from Dornoch westwards fell to Mr. Haldane while Mr. Macgregor remapped the high ground to the west and north-west of Golspie.

The noteworthy features of the ground revised by Mr. Read are a splendidly exposed complex of granite and granulite, and a varied hybrid series between scyelite and granite.

Granulites and Hornblende-schists. The groundwork of the country is formed by Moine granulites which only occasionally depart from the normal siliceous character of the East Sutherlandshire granulites. The variations from this type are due to an increase in mica-content or, rarely, to the presence of much epidote, but these variations are quite subordinate. The granulites are well seen in the Aberscross district and on both sides of Strath Càrnaig.

On Creag Dail na Meine in Strath Càrnaig, and elsewhere, there are pod-like bands of hornblende-schist in the siliceous granulites. The rock is a striped association of hornblende and felspar and is foliated in accord with the regional foliation of the surrounding granulites, but it has been noted that occasionally the elongation of the pods is markedly divergent to the bedding of the granulites. This suggests that these lenses represent basic dykes intruded before the foliation, by which the new-formed hornblende and felspar have been orientated in accord with the dominant stresses. A dyke of hornblende-schist, sometimes garnetiferous, has been noted by Mr. Haldane at Creag Asdale, 2½ miles N.W. of Clashmore; this dyke has contact-metamorphosed the granulites adjacent to it.

Granite and Granite-granulite Complex. The granite concerned in this complex is the eastern continuation of the Lairg granite

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of Sheet 102. The interior type of granite is an extremely coarse hornblende-biotite-granite often with porphyritic crystals up to 4 cms. in length. Two varieties can be distinguished, a hornblende-biotite-granite and a biotite-granite but, as yet, no characteristic distribution of the two types has been found. The granite holds abundant basic patches which are sometimes modified granulite, at other times probably altered scyelite (p. 111). The rock is well seen on both sides of Strath Fleet about Pitfure, Dalmore and Tressady. It was worked about 40 years ago by an Aberdeen firm at Rogart granite quarries, Dalmore, but, though it was of excellent quality for structural work, the black patches militated against its use for monumental work, for which it was mainly required.

The margin of the interior granite runs roughly north and south from Dalmore by Leathad to East Langwell. East of this line and west of the granulites of the Aberscross district there is a complex of granite and granulite. Several zones of the complex may be distinguished, though certain of them may be lacking at different localities. They are in order from west to east :—(1) interior granite, hornblende-biotite-granite and biotite-granite, with dark inclusions; (2) a fine-grained hornblende-granite; (3) a biotite-granite occurring in layered fashion as if replacing banded granulites; a few granulite relics occur, some rich in visible sillimanite; (4) an injection-zone of biotite-granite *lit-par-lit* with granulite; many aplite and pegmatite veins occur in this zone; (5) an inclusion zone in which there is almost as much granulite as biotite-granite; (6) a zone of apophyses, mainly granulite with innumerable aplite and pegmatite veins; (7) granulites with occasional pegmatite or aplite veins.

These zones may be studied on traverses from the interior granite eastwards along the road from Pitfure to the Mound. The layered granite of zone 3 is the only belt in which assimilation may have occurred; in this zone there are no definite boundaries between the granite and the relics of granulite, and these latter are thoroughly permeated by granite.

Scyelite and Scyelite-granite hybrids. In the 'Summary of Progress for 1920,'[1] rocks hybrid between scyelite and granite were described from Ach'uaine in Sheet 102. More numerous and far finer examples of these hybrids have been found by Mr. Read in Strath Fleet. In all, some thirty small hybrid masses have been mapped, the largest reaching only about $\frac{1}{6}$ square mile in area. The larger masses are situated near Loch Beag na h-Airidhe and are shown on the published map as epidiorite. Most of the scyelite masses are situated within the granite or the granite and granulite complex, but some, composed mainly of scyelite, are found in the granulites of Strath Càrnaig. As usual, these hybrid masses form conspicuous green knobs. The ultrabasic scyelitic member is a coarse olive-green rock, quite unfoliated, and composed of olivine, hornblende and biotite;

[1] *Mem. Geol. Surv.*, 1921, p. 46.

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by mixture with granite innumerable varieties are formed, consisting of hornblende, pyroxene, biotite, felspars and quartz; these have not yet been subjected to microscopic examination.

In the hybrid mass north of Loch Mòr na h-Airidhe the scyelite is in places veined by aplite which includes angular xenoliths of scyelite. These xenoliths are marginally altered to hornblende, thus suggesting that the non-sedimentary hornblende inclusions in the Rogart granite may represent modified scyelitic xenoliths.

Mr. Haldane has noted a small boss of hybrid rock half a mile N.N.E. of Loch Lannsaidh.

Old Red Sandstone. On the south side of Strath Fleet the high ridge running from north of Torroboll by An Droighneach to Loch Mòr na h-Airidhe is formed by a narrow belt of Old Red Sandstone conglomerate which lies unconformably on the granulites and granite at its north margin, but which is limited on its south side by a fault probably a continuation, as shown on the published one-inch map, of the Loch a' Vicair fault north of The Mound Station. Near Loch Mòr na h-Airidhe the Old Red Sandstone rocks fill up irregular hollows in the old floor.

The ground examined by Mr. Macgregor to the west and north-west of Golspie consists mainly of Old Red conglomerates and sandstones. Attention may be drawn to the prominent escarpment of conglomerate which runs north-westwards from the Silver Rock to Cnoc na Gaimhne and then turns north-eastwards to Loch Brora. Along this line the conglomerate rests on an eroded surface of crystalline schists. The junction for the most part is obscured by drift or peat, but in several of the small streams which descend to Strath Lundie the conglomerate is seen resting almost directly upon the schists. Perhaps the best section, however, is that exposed in the burn flowing N.N.W. from Ben Horn to join the Scottarie Burn near the 718-ft. point; in this burn, about 700 yards from its mouth, the conglomerates rest upon the denuded edges of the weathered and stained schists. The prevalent dip of the conglomerates varies from S.S.E. to S.E., while the foliation of the metamorphic rocks, for the most part following the original bedding planes, has an E.N.E. to N.E. dip often at high angles. The schists are normal siliceous or banded siliceous and semi-pelitic granulites with a good many reddish acid granite and pegmatite veins. The boulders in the overlying conglomerates appear to be entirely local in origin; all the types of rock noted among them occur abundantly in the schist or granite-schist areas immediately to the west. The conglomerate is generally rudely bedded, and the boulders are for the most part highly angular; in the coarser bands these may attain a diameter of 2 feet. A very marked crush-line, not noted on the existing maps, traverses the conglomerate exposed in the upper part of the Allt Coire Beinn Lundie. These conglomerates pass upwards through gritty and pebbly beds into dark-brown flaggy sandstones well seen in the small quarries at the side of the Dunrobin Glen road at Backies.

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One of the most interesting features of the Beinn Lundie area, not brought out on the published one-inch Sheet, is the extent to which the high ground is buried under peat. Rock exposures are confined to a few crags or to the sides of the glacial overflow channels mentioned below. Nearly the whole of Cnoc na Gaimhne again is under peat. The thickest peat noted was 12 feet at a height of just over 1,000 feet in Coire Cnoc na Gaimhne.

The upper portions of the Allt Creag a'Ghlinne and Allt Coire na Moine, and the hollow east-and-west feature in which Loch nan Caorach lies, are well-developed glacial overflow channels now almost dry. The direction of ice-movement in this area is clearly indicated by the boulders of grey Rogart granite (Dalmore type) scattered over Beinn Lundie. A few boulders referable to the scyelitic mixtures noted above (p. 110) by Mr. Read also occur.

Mr. Haldane reports that the western half of the area examined by him in the south part of one-inch Sheet 103 is occupied by crystalline schists, the eastern half by sediments of Old Red Sandstone age. The schists are the normal flaggy and colour-banded granulites which cover so much of eastern and central Sutherland; mica-schist bands occur fairly frequently, one of which, over a hundred yards wide, is well-exposed half-a-mile south of Loch Lannsaidh. In the area of Old Red Sandstone rock exposures are few. A small outcrop of conglomerate, resting unconformably on a weathered surface of schist, is seen in a gully 500 yards W.S.W. of Overskibo near the south margin of the Sheet. No further section of the junction is exposed until, four and a half miles to the north-east, a small stream on the south face of Ben Tarvie shows the broken and weathered schist overlain by conglomerate.

A prominent feature in the area is the long kame-like ridge of sand and gravel which extends for over two miles in a W.S.W. direction about a mile west of Dornoch. It rises abruptly to a height of 50 or 60 feet and embayed in its central part is the deep marshy hollow of Lochan Treathail. The materials comprising it are very uniform in character, consisting of sand and gravel with small well-rounded stones. Numerous isolated gravel mounds occur along the northern side of the River Evelix. It seems probable that this stream originally flowed eastwards to the sea near Dornoch, instead of turning sharply south-westwards at Evelix Bridge to enter the Dornoch Firth south of Skibo.

III.—PETROGRAPHICAL WORK

1. England and Wales

Petrographical work connected with England and Wales has chiefly been carried out by Dr. Thomas as the result of enquiries from private individuals and Government Departments.

Further investigation was undertaken for the Government Laboratory into the optical properties of certain artificial

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ected with the manufacture of explosives. A
is submitted by Mr. B. H. Cunnington of Devizes
ic site at Cannings Cross was of considerable
amination by Dr. Thomas and Mr. Hallimond
n-smelting had been carried out and that the
sisted of magnetite, fayalite and silica, indicated
of a method of smelting similar to that usually
acid-hearth process. The process probably
eduction of a rich ore by charcoal on a siliceous

repared for the memoir on the Nuneaton district
he pre-Cambrian and post-Cambrian igneous
gion. The post-Cambrian intrusions that are
associated with the Stockingford Shales are
interest on account of the extreme variation of
one and the same rock-mass. It would appear
re and gradation of types seen in many of the
e too rapid and pronounced to be explained by
ntiation of acid from basic material in place,
anation is to be sought in composite intrusion.
s are clearly referable to the proterobases, and
s picrites on the one hand and camptonites on
with.

2.—Scotland.

d Mr. Bailey have been largely concerned with
of the Island of Mull. In the petrological
e forthcoming Memoir on Sheet 44, in which
to the full the many chemical analyses made
ley, they have discussed the character of the
have given rise to the Tertiary igneous rocks

d convenient to assign a large proportion of the
at subdivisions of a magma-series. These
e specified as follows :—

	Silica Percentage.
Magma-Type	43—47
hyritic Central Magma-Type	47—55
ate and Sub-Acid Magma-Types	55—70
ma-Type	70—74

s of the present brief statement, the scope of
na-types is best outlined by the mention of
pes that represent them.

Magma-Type is represented by the bulk of
Lavas and Early Basic Cone-sheets, as well
dykes of the island. Its crystallization, in
is commonly basaltic or doleritic, and is
ng other things, by an abundance of olivine

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and purple-tinted augite. Where olivine retains its freshness residual analcite is quite commonly encountered.

2. *The Non-Porphyritic Central Magma-Type* is represented by such well-known basalt-lavas as that of Staffa which accompany the Plateau Basalt-Types. It recurs in force among the Later, or Central, Basalt Lavas; and where these have pillow-structure the crystallization tends to become variolitic in character. Among minor intrusions it is abundantly represented by variolite, tholeiite and quartz-dolerite; and, among the ring-dykes it figures prominently as quartz-dolerite and quartz-gabbro.

3. *The Intermediate and Sub-acid Magma-Types* are represented among minor intrusions by andesite (leidleite and inninmorite) and by a more crystalline rock-type designated craignurite. It may be mentioned that the andesites are often vitreous and partake of the nature of pitchstones. Among the major intrusions, the rock-type developed is an aberrant augite-diorite.

4. *The Acid Magma-Type* is represented by rhyolitic tuffs, etc., and by felsitic and granophyric intrusions.

The main order of manifestation of this magma-series seems to have been from basic to acid; at any rate, much of the igneous history of Mull can be accounted for by the assumption that there have been two major magmatic cycles, each leading from basic to acid, the last cycle being followed by a recrudescence of basic magma. In general terms the succession of magma-types may be elaborated as below :—

CYCLE I.

First Stage.—Eruption of Plateau Group of Lavas mostly referable to the Plateau Magma-Type.

Second Stage.—Eruption of Central Group of Lavas of Central Magma-Types, in large measure non-porphyritic.

Third Stage.—Intrusion-period of early granophyres giving rise to the first major intrusions of Mull. Paroxysmal explosions, and the intrusion of certain Early Felsites, etc.

CYCLE II.

First Stage.—Intrusion of Early Basic Cone-sheets, mostly of Plateau Magma-Type.

Second Stage.—Intermittent intrusion of Late Basic Cone-sheets of predominantly Non-Porphyritic Central Type.

The intrusion of these Cone-sheets is interrupted in point of time by the intrusion of extensive ring-dykes that range from Non-Porphyritic Central to Acid Magma-Type; among these ring-dykes acid types predominate towards the close of the period of their intrusion.

FINAL RECRUDESCENCE.

Some north-west dykes constitute the latest igneous rocks of Mull and include typical representatives of Plateau Magma-Type.

A feature of the Non-Porphyritic Central, and of the more crystallized representatives of the Intermediate Magma-Types is the free migration of their acid residuum, and the extent to

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which this residuum has exerted chemical action on the early-formed crystals. In several of the ring-dykes gravitation has resulted in the separation of the mobile acid residuum at the top of the intrusion, where it has consolidated as granophyre : a thousand feet lower in the intrusion there may be found quartz-gabbro with pseudomorphs after olivine, and in the interval every gradation between the extremes in uniform succession.

The exposed differentiation-columns of Mull reproduce all Magma-Types from (2) to (4) inclusive (*see* above). It is difficult, however to gauge the degree of genetic relationship of Magma-Types (1) and (2) to each other. The suggestion is made tentatively in the Memoir that Type (1) may have given rise to Type (2) as a consequence of deep-seated assimilation of siliceous country-rock.

The Magma-series outlined above does not include all the igneous rocks of Mull. There are

(1) *Alkaline Products*, such as mugearite, alkaline trachyte, alkaline syenite and bostonite; these though of small bulk are interesting as indicating divergences from the main path of magmatic differentiation.

(2) *Eucrite and Allivalite*, constituting the Ben Buie Complex.

(3) Rocks of Porphyritic Central Magma-Type.

The Ben Buie Complex, predominantly of eucrite, dates from near the close of the early Basic Cone-sheets (first stage, Cycle II).

The Porphyritic Central Magma-Type tends to associate itself in the Mull record with the Non-Porphyritic Central Type. It is largely represented among the lavas (second stage, Cycle I), and later on by such of the Early Basic Cone-sheets as are of later date than the Ben Buie Eucrite (close of first stage, Cycle II). In its variolitic, basaltic and doleritic crystallizations, it is marked by its abundant porphyritic basic felspars—a feature that fails only when a gabbroid texture is assumed.

The established silica-range of the type is from about 45 to 50 per cent. Compared with the Non-Porphyritic Central Magma-Type, the chemical features of importance are the relatively high percentage of Al_2O_3, and also, except in the acid representatives, of CaO. Other differences are relatively low percentages of K_2O, TiO_2, and total iron. A Porphyritic Central Lava from Mull with 47 per cent. SiO_2, has 21 per cent., Al_2O_3, and 13 per cent. CaO. A part of the Cuillin Gabbro of Skye, referable to the same Magma-Type, has 46 per cent. SiO_2, 26 per cent. Al_2O_3, and 15 cent. CaO.

If the Non-Porphyritic Central Magma-Type has originated through contamination of an original magma by siliceous country-rock, it is at least as probable that the Porphyritic Central Magma-Type owes its character to the assimilation of aluminous material.

Only one other matter of interest need be touched upon in this brief summary, namely, the results of pneumatolysis, or propylitization, to which Prof. Judd first directed attention.

Within a roughly circular area, ten miles in diameter, including most of the intrusions of the island, it is impossible to find a

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basalt-lava that contains olivine in a fresh condition; although, outside this limit undecomposed olivine is everywhere to be met with. The destruction of analcite, and to a less extent of basic felspar are changes that accompany the decomposition of olivine. The characteristic minerals of the pneumatolysed area are albite, epidote and chlorite.

Pneumatolysis has affected most of the intrusions of Central Mull in addition to the lavas, though frequently not to such a great extent. Thus the latest basalt-dykes of Mull have had their olivine decomposed where they traverse the Central region, but the area within which this change takes place is less extensive than in the case of the adjacent lavas.

It must be remembered that such Mull lavas as have escaped erosion are amongst the earliest igneous products of the district which are available for study, so that their relatively excessive pneumatolysation in the Central region might be explained as the result of cumulative attack. On the other hand, some early intrusions have suffered less than others of later date within the same region, and in such cases it would appear that the massive character of the rock, such as the Ben Buie Eucrite, acted protectively against pneumatolysis just as, to-day, it does against weathering.

Mr. Read has incorporated in the text of the Memoir on Sheet 54 (Moor of Rannoch), and supplemented where necessary, the descriptions of rocks from that Sheet furnished by Dr. Thomas.

Messrs. Read and Phemister have commenced petrographical work connected with Sheet 102 (Lairg), and the results of Mr. Phemister's preliminary examination of the alkaline igneous rocks of Sgonnan Beag are summarized on p. 107.

A re-examination of the trachytoid phonolite of Traprain Law, East Lothian, was undertaken by Mr. A. G. MacGregor. This examination, partly of an official character, resulted in the verification of the presence of nepheline and analcite and the recording for the first time of olivine and sodalite. After the petrographical work was completed a new complete analysis was made by Mr. Ennos in the Survey Laboratory. Mr. Ennos found that the percentage of chlorine would indicate the presence of at least 2·71 per cent. of sodalite. Full details and references to literature will be found in a paper by Mr. MacGregor and Mr. Ennos which has appeared in the Geological Magazine.[1]

IV.—CHEMICAL WORK

The analytical work for the past year was of an especially varied character. To complete the Report on British Refractory Materials six fireclays were analysed and, for a memoir on Sedimentary Iron Ores, an examination was made of eleven ores with a

[1] 'The Traprain Law Phonolite,' part i, by A. G. MacGregor, M.C., B.Sc.; part ii, by F. R. Ennos, B.A., B.Sc., A.I.C., *Geol. Mag.*, vol. lix, 1922, pp. 514–523.

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view to determining the iron content and also the mineral composition. A description of the method employed is given below, together with two examples of the analyses.

The most noteworthy of the five igneous rocks analysed was the Traprain Law phonolite, in which the presence of sodalite, first detected microchemically, was confirmed by the chemical analysis.

Two samples of Welsh and Scottish orthite were obtained from the parent rocks, in a state of high purity, by means of a magnetic separator; the analyses of the minerals are now in progress.

An analysis was made of the Houston Marl, and the composition of the soluble and insoluble portions determined after extraction with acid followed by alkali.

An examination was also made of a method of cement testing on samples supplied by the Building Research Board.

To determine chemically the mineral composition of the sedimentary iron ores a method was devised which enables the carbonates, phosphates, and ferrous aluminium silicates(chamosite, etc.), to be removed by solution, leaving the other minerals unacted upon, (quartz, felspar, mica, clay, haematite or göthite). After numerous trials it was found that, whereas the latter minerals were practically unattacked after treatment with a moderate excess of $\frac{N}{2}$ HCl. at 100° C. for 10 minutes, followed by extraction for 10 minutes with 10 per cent. Na_2CO_3 solution at the same temperature, the iron, calcium and magnesium carbonates and phosphates as well as the ferrous aluminium silicate were completely dissolved. Accordingly, analyses were made of the soluble portions obtained in this way from the various ores. Determinations were also made of carbonate, phosphate, soluble sulphate and ferrous oxide on separate portions of the material by treatment with $\frac{N}{2}$ acid. The insoluble residues were washed, dried and weighed, and kept for microscopic examination.

After satisfying the phosphoric acid and sulphuric acid with lime to form calcium phosphate and sulphate respectively, the remaining lime together with the magnesia was calculated to carbonate; any carbon dioxide left was then assigned to combination with ferrous oxide. The remaining constituents of the soluble portion consisted of ferrous oxide, ferric oxide, alumina and silica. On calculating the percentages of these oxides to molecular proportions and combining the ferric oxide and alumina, the molecules of FeO, $Fe_2O_3 + Al_2O_3$ and SiO_2 were found to be very nearly as 3 : 1 : 2, the ratio in which they occur as chamosite [3 FeO, $(Al\ Fe)_2O_3$, 2 $SiO_2 + nH_2O$]. By this means the presence of chamosite in the ores was proved and the percentage of total oxides of chamosite found. It was not possible to determine the amount of water in the chamosite of the ores as other hydrous minerals were present.

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E. 13702. Lab. No. 697.

Clay Ironstone with heavy ferric ooliths, underlying Lower Lias shale. Top Bed, Yarborough Pit, Frodingham, Lincolnshire.

Lab. No. 714.

Ironstone. Pecten Seam. Upleatham Mine, Marske, Yorkshire.

The percentages given are all calculated on the original rock powder.

Soluble Portion.	Lab. No. 697. Per cent.	Lab. No. 714. Per cent.
SiO_2	4·15	12·13
Al_2O_3	2·98	9·32
Fe_2O_3	1·55	2·71
FeO	10·00	36·45
MnO	·46	·24
CaO	4·47	2·09
MgO	1·93	3·75
P_2O_5	·88	·52
CO_2	6·72	14·16
SO_3	—	·14
Insoluble Residue (dried at 105° C.)	61·39	11·23

Calculated mineral composition of soluble portion :

$Ca_3(PO_4)_2$	1·92	1·13
$CaSO_4$	—	·24
$CaCO_3$	6·13	2·46
$MnCO_3$	·75	·39
$MgCO_3$	4·05	7·88
$FeCO_3$	4·24	23·20

The remaining silicate has the composition :

		Molecular Ratios.		Molecular Ratios.
SiO_2	4·15	2	12·13	2
Al_2O_3	2·98	1·11	9·32	1·07
Fe_2O_3	1·55		2·71	
FeO	7·37	2·96	22·05	3·03
Percentage of total oxides of chamosite in ore	16·05		46·21	

Anal. F. R. Ennos.

21173. Lab. No. 704.

Traprain Law Phonolite. Interior part of Traprain Law Quarry 1-in. sheet 33. 6-in. Haddington 10 N.E.

SiO_2	56·89
TiO_2	·33
Al_2O_3	19·11
Fe_2O_3	2·04
Cr_2O_3	nt. fd.
FeO	3·44
MnO	·18
(CoNi)O	nt. fd.
CaO	2·15
BaO	·01
MgO	·35
K_2O	6·35
Na_2O	6·88
Li_2O	nt. fd.
H_2O at 105° C.	·54
H_2O above 105° C.	1·68

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	·15
	·17
	trace
	nt. fd.
	·22
	100·49
Cl	·05
	100·44

Anal. F. R. ENNOS.

the Strathmore Meteorite, which was made in the in 1921 and published in the *Mineralogical Magazine* low :—

	Attracted by magnet.	Unattracted by magnet.	Bulk-analysis.
	52·60	·29	7·31
	9·05	·05	1·26
	·36	—	·05
	1·36	4·29	4·00
	·78	2·46	2·29
	6·34	44·34	40·32
	—	·16	·14
	—	2·89	2·57
	—	·50	·44
	—	·39	·35
	3·64	14·05	12·99
	nt. fd.	·33	·29
	trace	2·07	1·84
	6·68	27·03	24·96
	—	·12	·11
	—	1·01	·90
	—	·19	·17
	·08	·25	·23
	—	·03	·03
	18·97	—	—
	99·86	100·45	100·25

of the Olivine - 3·27 Mg_2SiO_4 + 1 Fe_2SiO_4.

ition of the meteorite as calculated from the bulk-ove composition of the olivine :

·65		
7·64	10·93	Felspar.
2·64		
—	·27	Ilmenite.
—	·65	Chromite.
—	·51	Magnetite.
—	·56	Chlor-apatite.
12·62		
28·51	41·13	Olivine.
6·63		
·54		
2·14	30·91	Bronzite.
21·60		

intock and F. R. Ennos, *Min. Mag.*, vol. xix, No. 98,

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Fe	4·00	6·29	Troilite.
S	2·29		
Fe	7·31	8·62	Nickel-Iron.
Ni	1·26		
Co	·05		
H_2O	—	·17	Water.
	100·04		

Percentage of nickel iron	8·62
Ratio of Fe to Ni in nickel-iron	5·80
Ratio of MgO to FeO in olivine	3·27
" " " pyroxene	4·25
" " " ferromagnesian silicates	3·47

Anal. F. R. Ennos.

V.—PALÆONTOLOGICAL WORK

1. England and Wales

During the preparation of the Sheet Memoirs on the Beaconsfield and Aylesbury districts the assistance of Mr. J. Pringle and Mr. C. P. Chatwin was enlisted. To the first of these memoirs Mr. Pringle contributed a chapter on the underground rocks; in the Aylesbury district an examination of the Jurassic and a part of the Cretaceous rocks was made by these geologists, who wrote the chapters on these formations. Mr. Chatwin also visited the districts of Hertford and Dartford and has been engaged in palæontological work in connexion with the Sheet Memoirs on those areas now in course of preparation.

Mr. Pringle has made visits to the Dorset coast in order to examine certain portions of the Kimmeridge and Portland succession displayed near St. Alban's Head and in the Isle of Portland. He studied in particular a series of clays and sands, above the Pallasianus Zone and below the Portland Stone, which are absent in the Swindon and Aylesbury areas. It has been shown that in those districts the zone of '*Perisphinctes*' *gorei* rests unconformably on a remnant of the Pallasianus Zone.[1] Between these horizons there are present in the neighbourhood of Chapman's Pool, near Kimmeridge, some 240 feet of sands and clays, the ammonites of which have not yet been adequately studied. These beds, exposed in a steep cliff-section, are difficult of access, so that palæontological material from them has hitherto scarcely come under examination. It can now be stated that several ammonite-zones, as yet undefined, are included in this series. Some of the specimens permit close comparison with certain ammonites seen in the cores from the upper part of the expanded Kimmeridge series passed through in the Penshurst boring in Kent. It must be recognised that the fullest developments of

[1] C. P. Chatwin and J. Pringle. 'The Zones of the Kimmeridge and Portland Rocks at Swindon,' in 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 167. *See also* 'The Geology of the Country around Aylesbury and Hemel Hempstead' (*Mem. Geol. Surv.*), 1922 [issued 1923] p. 6.

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the Kimmeridge formation in this country are found in Dorset and underground in the area of the Weald.

Much work has been done by Dr. Kitchin and Mr. Pringle in the final preparation of the memoir on 'The Concealed Mesozoic Rocks in Kent,' written in collaboration with Mr. G. W. Lamplugh. They have included a comparison of the Kimmeridge Clay of Kent with that of the type area in Dorset. The information is set forth in a zonal table in which are recorded the vertical ranges of a number of the commoner and more characteristic fossils of the Kimmeridge series.

Through the kindness of Mr. E. O. Forster Brown, Mr. Pringle has been permitted to visit the site of a deep boring at Adisham, near Canterbury, and to examine the cores of Cretaceous and Jurassic rocks passed through. This boring was still in progress at the end of 1922. Information previously obtained from three borings put down near Southery, Norfolk, forms the subject of an Appendix (p. 126). The results are of considerable stratigraphical interest.

Dr. L. F. Spath visited Folkestone on behalf of the Geological Survey in order to study the Gault succession in detail. The need for a zonal revision in accordance with the progress of modern work had for long been felt. As a result of his field-examinations and the monographic study of the ammonite-fauna of the Gault upon which he has for some time been engaged, Dr. Spath has arrived at important conclusions concerning the zonal classification and has detected and defined the gaps in the sequence at Folkestone. Some of his results have been embodied in a Report published during the year.[2] In continuation of these studies, Dr. Spath has examined the ammonite-faunas and the zonal characters of the deposits below and above the Gault. He deals with this subject in a paper published herewith as an Appendix (p. 139).

Among the fossils added to the collections during the year is a representative suite of specimens from the Bargate Stone, of Upper Aptian age, from localities near Godalming. This comprises many indigenous species as well as a number of rolled and polished specimens derived from the Oxford Clay. Among the Aptian fossils are some fine ammonites and *Nautili;* and particularly noteworthy is a cirripede-capitulum having the plates united in place, a rare state of preservation.

The following specimens in the Museum have been figured or described in publications :—

IN THE PALÆONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1920. (PUBLISHED 1922.)

A Monograph of the British Palæozoic Asterozoa. (Part V.)

BY DR. W. K. SPENCER, M.A.

Platanaster ordovicus *Spencer*, pl. xiv, figs. 1, 2, 3, p. 171 (2 specimens).
Palasterina primaeva (*Forbes*), text-fig. 144, p. 203.

[1] L. F. Spath, 'Excursion to Folkestone' *Proc. Geol. Assoc.*, vol. xxxiv, 1923, p. 70.

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A Monograph of the Fossil Insects of the British Coal Measures. (Part ii).

By Mr. H. Bolton, M.Sc., F.R.S.E.

Archimylacris hastata *Bolton*, pl. vii, figs. 1a, b; text fig. 33, p. 104 (2 specimens).
,, obovata *Bolton*, pl. vii, figs. 4a, b; text-fig. 35, p. 110 (2 specimens).
,, sp., pl. vii, figs. 5, 6, pp. 112, 113 (2 specimens).
Phyloblatta sulcata (*Bolton*), pl. viii, figs. 1a, b; text-fig. 36, p. 114 (2 specimens).
Hemimylacris obtusa *Bolton*, pl. viii, fig. 7; text-fig. 38, p. 122.
Orthomylacris lanceolata *Bolton*, pl. ix, fig. 5; text-fig. 43, p. 134.
Archimylacris pringlei *Bolton*, pl. x, fig. 3, p. 146.

In the Annals and Magazine of Natural History, Volume IX, Ninth Series.

The Morphology of some Cretaceous Cirripedes.

By Mr. T. H. Withers.

Scalpellum (Cretiscalpellum) unguis (*J. de C. Sow.*), pl. v, figs. 5, 6, p. 371 (2 specimens).

In the Geological Magazine, Volume LIX.

Notes on the Fauna of the Lower Devonian Beds of Torquay.

By Dr. F. R. Cowper Reed, M.A.

Leiopteria (Actinopteria ?) anisota (*Phill.*), p. 270.
Nuculites (Cleidophorus) subovatus *Reed*, p. 274.
Bellerophon (Pedasiola) *aff.* tumidus (Sandberger) ?, p. 308.

In Type Ammonites, Volume IV.

By Mr. S. S. Buckman.

Tulites subcontractus (*Morris & Lycett*), pl. cclxx, figs. 1, 2, p. 45.
Madarites madarus *S. Buckm.*, pl. cclxxiA, figs, 1, 2; pl. cclxxiB, p. 46.
Bullatimorphites bullatimorphus *S. Buckm.*, pl. cclxxiiA; pl. cclxxiiB, p. 47.
Morrisites morrisi (*Oppel*), pl. cclxxiii, figs. 1, 2, p. 48.
Proplanulites koenigi (*J. Sow.*), pl. cclxxxi, figs. 1, 2, 3, p. 36.
,, lobatus *S. Buckm.*, pl. ccexxx, figs. 1, 1a, 2, 2a, 3, 3a.
,, arciruga *Teisseyre*, pl. ccexxxi, p. 38.
Gowericeras gowerianum (*J. de C. Sow.*), pl. cclxxxvii, figs. 1, 1a, b; pl. cclxxxvii*, figs. 1, 1a, b.
,, ventrale *S. Buckm.*, pl. cclxxxviii.
Galilaciceras trichophorum *S. Buckm.*, pl. ccxci, figs. 1, 2, 2a.
Galilaeanus crucifer *S. Buckm.*, pl. ccxciii, figs. 1, 2.
Galilaeites curtilobus *S. Buckm.*, pl. ccxciv, figs. 1, 2.
Zigzagites imitator *S. Buckm.*, pl. ccci, figs. 1, 2.
Parkinsonites fullonicus *S. Buckm.*, pl. ccccii, figs. 1, 2, 2a; pl. ccccii*, figs. 1, 2, 2a.
Prorsisphinctes omphalicus *S. Buckm.*, pl. ccexxvi, figs. 1, 2, 3.
Homoeoplanulites homoeomorphus *S. Buckm.*, pl. ccexxviii, figs. 1, 1a, 2, 3, 3a.
Trinisphinctes trinus *S. Buckm.*, pl. ccexxxii, figs. 1, 2.
Toricellites approximatus *S. Buckm.*, pl. ccexxxvi, figs. 1, 1a, b, 2, 3, 3a.
Phlyseogrammoceras dispansum (*Lycett*), pl. ccexl.
Suspensites suspensus *S. Buckm.*, pl. ccexlvi, figs. 1, 2.

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Kamptokephalites kamptus *S. Buckm.*, pl. cccxlvii, figs. 1, 2.
Pleurocephalites folliformis *S. Buckm.*, pl. cccxlviii, figs. 1, 2.
Pectinatites pectinatus (*Phill.*), pl. ccclivB, figs. 1, 2, 2a, b, c.
Korythoceras korys *S. Buckm.*, pl. ccclxi, figs. 1, 1a, b, 2, p. 17.

2. Scotland.

In connexion with the revision of the coalfields systematic collecting from Carboniferous sections was prosecuted in the Douglas district and in Ayrshire, while cores from a number of borings in various parts of the country were also examined. A representative collection has been made from the Jurassic Rocks of Ardnamurchan, Argyllshire.

The Carboniferous Invertebrates were dealt with in the Survey Office by Dr. G. W. Lee, and the plants were as usual submitted to Dr. R. Kidston. The materials obtained by Mr. Manson in the Douglas district include a suite of well-preserved *Productus giganteus* (Mart.), collected zonally from two definitely ascertained horizons. These specimens, which obviously belong to the same stock, may provide a step towards the difficult task of recognising evolutionary series in Carboniferous brachiopods. They belong to the typical large, convex and deeply furrowed form. From the evidence at hand it would appear that the species was at its acme during the deposition of the lower stratum (in the 'Prod. giganteus bed'), the specimens from the higher bed in the 'Main Limestone' evincing catagenetic loss of the furrows in the umbonal region. Whether the smaller giganteid *Producti*, occasionally found much higher up in the Index Limestone, are the actual descendants of the form just considered cannot be shown, owing to absence of connecting links; but it is interesting to note that they are quite devoid of furrows and simulate the early giganteids of the Northumbrian Province. Should the phenomenon recorded here prove invariably constant it would furnish a useful means of distinguishing the Main Limestone from the underlying 'Productus giganteus Limestone.' Another *Productus* in which changes, presumably evolutionary, have been observed is *P. latissimus* J. Sow. Here the change would appear to be anagenetic, in the direction of increased spinosity. This change is observable between a form which occurs in the Hollybush Limestone and *P. latissimus* as commonly found much higher up in the Index Limestone.

P. longispinus J. Sow., being one of the commonest of Scottish Carboniferous fossils, would prove an invaluable index-form if a genetic sequence could be established, but the difficulty is to separate the various stocks that go under that name. However, it seems that the most coarsely ribbed of the Scottish forms currently designated '*P. longispinus*' does not occur above the Lower Limestone Series, a point which, if established, would be of practical value.

Further records were obtained of the *Edmondia punctatella* bed below the Calmy Limestone. The occurrence is now known to extend eastwards to the shore of the Firth of Forth.

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As Mr. S. S. Buckman is still engaged on the examination of materials from N.E. Scotland, the ammonites obtained in Ardnamurchan have not yet been submitted to him. Cursory examination in the Survey Office shows, however, that there is a fairly complete sequence from the Lower Lias to the base of the Great Estuarine Series. The Broadford Beds (Sinemurian) at and near Mingary Castle have yielded distinctive ammonites, but the Pabba Shales (Charmouthian) are, unlike their representatives in Mull, poor in recognisable fossils and probably not zonally subdivisible. The small exposures of Scalpa Sandstone (Domerian) offer no features of palæontological interest. The Upper Lias shows a sequence similar to that obtaining in Raasay, and the Ironstone has yielded two species of ammonites not yet known from the Raasay Ironstone. The Inferior Oolite is thicker than in S.E. Mull, and tends towards the Skye type of development. In spite of considerable physical difficulties due to intractability of the baked strata, Mr. Manson was successful in obtaining a number of characteristic specimens. It is probable that critical study will reveal the presence of several zones, possibly from *scissum* to *blagdeni*. The attribution to the Estuarine Series of a thin outcrop of black shales rests on the presence of a large *Estheria* referred to *E. murchisonae* Jones, a species founded on specimens from the Estuarine Series of Skye.

A fish-tooth, probably derived, found in association with a coaly deposit in Ardnamurchan, was submitted to Dr. A. Smith Woodward, who stated it to show resemblance to the Upper Cretaceous *Oxyrhina mantelli* Ag.

VI.—MUSEUM OF PRACTICAL GEOLOGY

The exhibits of British economic minerals and rocks have continued to increase and special attention has been paid to fireclays, abrasives, silica rocks, roadstones and iron ores. The collection of building stones has been cleaned and in part revised. The recent work of the Survey is now illustrated in a special case containing typical Survey maps, memoirs and other publications, whilst the latest edition of the quarter mile map of England and Wales has been mounted and is now exhibited on one of the walls.

A new edition of the Short Guide to the Museum has been issued.

The Strathmore meteorite has been examined petrographically and chemically and the results published.

A large number of enquiries has been dealt with in the Museum, the Library and Map Room and considerable time has been occupied in dealing with a growing demand on the part of schools, scientific societies and clubs for demonstrations in the Museum.

The examination of the English and Welsh Iron Ores has been continued. By means of a series of analyses of which an outline has been given on p. 117, it has been shown that the chloritic

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mineral chamosite, with the formula $2SiO_2$, Al_2O_3, $3FeO$, aq., is an essential constituent of the Cleveland and Frodingham ironstones. This mineral represents the 'green silicate' of uncertain composition to which the excess of ferrous iron has in the past been assigned. Apart from a small amount of glauconite this would appear to be the only ferrous silicate present in the ordinary bedded ores, and it may be anticipated that the analysis of the Marlstone and Northampton ores will yield similar results. The chamosite occurs in part as ooliths and as distinct crystalline flakes, but mainly as an aggregate of minute flakes parallel with the bedding, and at times is apparently amorphous. A variable but usually small residue, insoluble in the acid used, consists of non-ferruginous clay substance, quartz grains, &c., and mainly represents accidentally derived material from the adjoining shale or sandstone facies. Chamosite is present in the normal Lower Lias shale at Frodingham, and in the Cleveland interbedded shale. The distinction between the iron ore and the adjoining rocks consists in the relative subordination of the detrital constituents and the dominance of the chemically precipitated minerals chamosite and siderite. Carbonation of the chamosite mud is an almost universal feature, no doubt resulting from the decomposition of dead organic matter below the exposed surface. It is to this carbonation that the value of the ore is mainly due, for the presence of very little additional silica is sufficient to make a pure chamosite ore commercially valueless.

The Frodingham mudstone and limestone contain ooliths composed of nearly pure hydrated ferric oxide Fe_2O_3, H_2O. These are brown in thin sections, and have a radial-fibrous and concentric structure analogous with that of chamosite ooliths. Similar ooliths occur at Claxby and in the Kentish iron ores.

On the whole the present results indicate that the bedded ores are substantially in the condition in which they were deposited, the only 'secondary' alteration of general importance being the carbonation of chamosite during the period of cementation. Calcite in shells is generally well preserved and is very rarely replaced by siderite. This is of special interest in view of the opinion, once widely quoted, that ores such as the Cleveland ironstone result from the replacement of oolitic limestones.

The maximum carbonation of an unweathered marine ironstone was observed in the Cleveland 'Dogger Stone' which contained only 15 per cent. of chamosite with 52 per cent. of siderite. It is of great interest to note that the analyses of the Coal Measure ironstones in the 'Iron Ores of Great Britain' indicate that these rocks contain no chamosite. This corresponds with the conditions of strong carbonation obtaining during their deposition, and probably is an equally characteristic difference between the associated shales and those of formations such as the Lias.

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APPENDIX I

On the Concealed Mesozoic Rocks in South-West Norfolk

By J. Pringle

Introduction

During the year 1920, three boreholes were drilled in the Fen lying to the east of Southery, and the results of two of these undertakings yield much information concerning the underground range of the Jurassic rocks beneath the Cretaceous formations in the south-west corner of Norfolk. At the same time the borings reveal important facts regarding the Lower Cretaceous strata, and throw some light on the movements and denudation of these rocks prior to the deposition of the Upper Gault.

Unfortunately, the cores obtained from the borings were of the narrow diameter of 2 inches, but this handicap was to some extent lessened by the fossiliferous character of many of the formations, and the finding of numerous specimens of zonal value. These have served as valuable guides in estimating the thickness of each formation passed through. I have to acknowledge the able assistance of Mr. A. Templeman in collecting the fossils, and to thank Mr. S. S. Buckman for some help in the naming of the ammonites.

The chief results of the deepest boring may be summarized as follows :—

(1) The Chalk appears to pass conformably downwards into the Upper Gault.

(2) The base of the Upper Gault rests unconformably on the basement-beds of the Sandringham Sands, which in turn lie unconformably on the Kimmeridge Clay.

(3) From the local top of the Kimmeridge Clay down to the base of the Oxford Clay there appears to be a complete sequence, so far as can be ascertained. All of the formations are remarkably thin, particularly the Kimmeridge Clay, which, although nearly completely represented, is only 125 feet thick in this boring. The Kellaways Rock appears to be absent.

(4) The Forest Marble rests unconformably on the Marlstone of the Middle Lias. This boring was stopped in the Lower Lias without proving the full thickness of the subdivision.

The lithological characters of the Lower Lias are not unlike those of the corresponding beds at the outcrop throughout the Midlands. The subdivision consists mainly of fine clays with hard calcareous rock-bands. Beds of coarse sediment are absent, and consequently there is no indication of the close proximity of the ridge of Palæozoic rocks proved in the Culford boring.

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Although it is now clear that deeper water prevailed in the area north of Culford, the sections suggest that the Jurassic formations soon wedge out eastwards on a rising slope of Palæozoic rocks. Indeed, the results of the borings amply confirm the observations of Mr. G. W. Lamplugh, who has pointed out that the Jurassic rocks 'as a whole have their greatest thicknesses and fullest sequence in the west and become attenuated by gaps and unconformities eastwards,'[1] Clearly this remark can be extended to include the Lower Cretaceous strata and the whole of the Lower Gault in West Norfolk and elsewhere. We can thus recognize the stratigraphical unity of the Upper Gault with the overlying Cenomanian. The term Upper Gault as here used must be taken to include the Junction Bed VIII of Folkestone as its base. The behaviour of these upper beds of the Gault, showing as they do, transgressive extensions over wide areas in this and other countries,[2] emphasizes the value of Prof. Barrois's classification which brought out the stratigraphical connexion between the Upper Gault and the overlying Chalk.

The Sections.

(A.) Boring at Decoy Farm about 1¾ miles E. of Southery, Norfolk. One inch New Series Ordnance Map 173; Old Series Geological Map 65. Height above Ordnance Datum about 5 feet.

		Thickness. Ft.	in.	Depth. Ft.	in.
Alluvium. (No cores, samples only).	Black peaty surface soil	1	6	1	6
	Yellowish sandy clay	9	6	11	0
	Bluish clayey sand	11	9	22	9
	Fine bluish-black sand with clay ...	17	3	40	0
Kimmeridge Clay	Black shelly clay with numerous bands of greenish-black oil-shale. *Saccocoma sp.*, *Lucina minuscula* Blake at 40½ ft.	26	1	66	1
	Dark shale with iron pyrites	0	0¾	66	1¾
	Black shelly clay with ½-inch band of cement stone at 82½ ft. *Exogyra virgula* (Defr.), *Protocardia morinica* (de Lor.), and *Amoeboceras krausei Salfeld* numerous at base	26	4½	92	6
	Brownish-black inferior oil-shale with layers of finely comminuted ammonite-shells	1	9	94	3
	Black shelly clay	11	9	106	0
	Cement stone	2	0	108	0
	Black clay with some pale calcareous rock-bands. *Exogyra virgula* (Defr.) and *Rasenia sp.* at 136 ft.	31	6	139	6
	Cement stone	1	0	140	6

Bottom of boring at 140½ feet.

[1] G. W. Lamplugh, 'The structure of the Weald and Analogous Tracts,' *Quart. Journ. Geol. Soc.*, vol. lxxv, p. lxxxvi, 1920.

[2] See F. L. Kitchin and J. Pringle, 'On the Overlap of the Upper Gault in England and on the "Red Chalk" of the Eastern Counties,' *Geol. Mag.*, vol. lix, 1922.

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(B.). Boring on Methwold Common, about 3½ miles E. of Southery, Norfolk. One-inch New Series Ordnance Map 173; Old Series Geological Map 65. Height above Ordnance Datum 7 ft.

		Thickness. Ft.	in.	Depth. Ft.	in.
Superficial Deposits	Peat	13	9	13	9
	Fine white sand	1	3	15	0
	Coarse sand with small flint pebbles	15	0	30	0
Gault 36 ft.	Fine sandy clay	21	0	51	0
	Fine white clay with many chalk-like pellets	15	0	66	0
	Unconformity.				
Lower Greensand	Hard greyish-brown gritty glauconitic sand-rock with small phosphatic nodules; iron pyrites at base	1	4	67	4
	Unconformity.				
Kimmeridge Clay 121 ft. 1 in.	Black shelly clay with numerous bands of greenish-black oil-shale. *Saccocoma sp. Lucina minuscula* Blake, *Ostrea sp.* and Fish remains	22	8	90	0
	Black shelly clay with thin inferior oil-shale in places. Many layers of fine 'shell-dust'	52	0	142	0
	Cement stone	1	0	143	0
	Black shelly clay with *Exogyra virgula* (Defr.)	9	0	152	0
	Pale and dark shelly clays	7	5	159	5
	Cement stone	0	4	159	9
	Bluish-grey clay with *Involuticeras* cf. *desmonotus* (Opp.)	12	5	172	2
	Cement stone	0	4	172	6
	Bluish-grey clay with *Exogyra virgula* (Defr.)	8	6	181	0
	Grey limy shelly clay with fragments of large ammonites, *Pictonia* ?, and *Pholadidea sp. nov.* ?	7	5	188	5
	Pale grey compact limestone	0	10	189	3
Corallian (Ampthill Clay) 50 ft. 9 in.	Bluish-grey limy clay, becoming darker below. *Amoeboceras serratum* (J. Sow.) at 212 ft. and *Protocardia delibata* (de Lor.)	30	4	219	7
	Pale smooth claystone	0	3	219	10
	Grey marly clay	2	5	222	3
	Pale smooth compact limestone	0	6½	222	9½
	Grey marly clay with a 3-inch band of pale compact limestone at 226 ft. 3 in.	7	5	230	2½
	Pale grey compact limestone	0	7½	230	10
	Grey marly clay with *Alaria sp.*	8	4	239	2
	Soft black clay (cores imperfect)	20	10	260	0
	Soft smooth grey clay	3	3	263	3
	Pale smooth compact claystone	1	0	264	3
	Smooth dark clays (cores badly broken); *Quenstedtoceras sp.* at 270½ ft.	13	6	277	9
	Pale compact grey limestone	0	5	278	2
	Dark grey marly clay	2	4	280	6
	Pale grey limestone	0	3	280	9
	Soft black clay	2	7	283	4
	Pale grey fine-grained limestone	0	10	284	2

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		Thickness. Ft.	in.	Depth. Ft.	in.
Oxford Clay 159 ft. 4 in.	Soft grey clay	5	0	289	2
	Pale grey fine-grained limestone ...	3	7	292	9
	Dark grey marly clay	3	6	296	3
	Pale grey fine-grained limestone ...	0	3	296	6
	Black shaly clay; *Grammatodon sp.* ...	7	6	304	0
	Soft greenish-brown clay with *Quenstedtoceras sp.*, *Pinna* cf. *mitis* Phill. ...	5	9	309	9
	Grey earthy limestone	0	3	310	0
	Greenish-grey marly clay with numerous specimens of *Quenstedtoceras*	13	6	323	6
	Grey earthy limestone	0	6	324	0
	Soft black clay with some hard bands; *Alaria trifida* Phill.	12	6	336	6
	Pale grey shelly clay with two hard bands; *Quenstedtoceras* cf. *lamberti* (J. Sow.), *Pinna mitis* Phill. at 337 ft.	17	0	353	6
	Greenish tinged brownish-grey marly clay with some hard calcareous bands; *Cosmoceras* cf. *jason* (Rein.), *Cosmoceras* cf. *stutchburii* (Pratt), *Perisphinctes* cf. *comptoni* (Pratt), *Cucullaea sp.*, *Gryphaea* cf. *bilobata* J. de C. Sow., *Pseudomonotis sp.*, and *Serpula vertebralis* J. de C. Sow	40	6	394	0
	No core	4	6	398	6

Bottom of Boring 398½ ft.

(C.). Boring, 1 mile N.E. of Severals House, 4½ miles E.N.E. of Southery. One-inch New Series Ordnance Map 159; Old Series Geological Map 65. Height above Ordnance Datum about 10 feet.

		Thickness. Ft.	in.	Depth. Ft.	in.
Superficial Deposits	Soil and crumbly peat	2	0	2	0
Lower Chalk 38 ft.	Soft white chalk with some fine grains of glauconite	30	0	32	0
	Greyish-white finely glauconitic sandy marl with a hard chalk-band, 1 ft. thick, at 38 feet. Numerous specimens of *Ostrea canaliculata* (J. Sow.)	8	0	40	0
Gault 59 ft. 8½ in.	Bluish-grey clay, drying almost white, *Inoceramus sulcatus* Park. and *Belemnites minimus* List. in lower part ...	34	0	74	0
	Soft bluish clay with many chalk-white pellets	25	8½	99	8½
	Unconformity.				
Lower Greensand 3 ft. 0½ in.	Hard grey sandrock with numerous grains of glauconite and small well-rounded black phosphatic nodules ...	0	3½	100	0
	Brownish-grey muddy sand with brown rusty specks	2	0	102	0
	Hard dark grey sandrock with numerous grains of glauconite and small well-rounded black phosphatic nodules. Iron pyrites abundant in matrix at base	0	9	102	9

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		Thickness. Ft.	in.	Depth. Ft.	in.
	Unconformity.				
Kimmeridge Clay 125¼ ft.	Black shelly clay with numerous beds of greenish-brown oil-shale; *Saccocoma* at 119 ft. 9 in. with *Lucina minuscula* Blake, etc.	25	9	128	6
	Brownish-grey shale with *Modiola autissiodorensis* (Cott.)	3	3	131	9
	Grey cement stone	0	8	132	5
	Black shelly clay with thin impure oil-shales; *Exogyra virgula* (Defr.) at 134 ft....	10	7	143	0
	Soft black shelly clay with numerous specimens of *Amoeboceras krausei* Salfeld at 162½ ft. and *Lingula ovalis* J. Sow...	36	2	179	2
	Hard limy clay	0	6	179	8
	Soft black shelly clay with a grey cement stone, 10 inches thick, *Protocardia morinica* (de Lor) ...	2	0	181	8
	Bluish grey shelly clay with a 3-inch band of earthy limestone; *Rasenia* cf. *phorcus* (Fontannes), *Involuticeras* cf. *desmonotus* (Opp.) between 208 ft. and 210 ft.	30	8½	212	4½
	Grey bituminous limestone	0	6	212	10½
	Black shaly clay with bands of soft lumpy clay; *Rasenia sp.* at 215 ft....	9	1½	222	0
	Pale grey limy clay with fragments of large smooth ammonites, *Pictonia?*	6	0	228	0
Corallian (Ampthill Clay) 52 ft. 1 in.	Soft black shelly clay	3	2	231	2
	Grey earthy limestone	0	10	232	0
	Dark grey shelly clay with *Amoeboceras* cf. *serratum* Salfeld at 247 ft. ...	21	0	253	0
	Pale claystone	0	4	253	4
	Soft dark grey clay	10	6	263	10
	Grey clayey limestone	0	8	264	6
	Crumbly grey clay with *Cardioceras sp.*	3	9	268	3
	Hard pale claystone with *Cardioceras sp.*	0	6	268	9
	Soft grey clay	3	5	272	2
	Pale compact earthy limestone ...	0	11	273	1
	Grey slate-coloured clay with *Cardioceras sp.* at 277 ft.	7	0	280	1
	Grey clay (much core lost in passing through this bed)	21	4	301	5
	Pale grey limestone	0	11	302	4
	Grey marly clay	4	10	307	2
	Pale grey limestone	0	4	307	6
	Smooth bluish-black clay	12	6	320	0
	Grey compact limestone with marly parting	2	0	322	0
	Soft dark clay	9	6	331	6
	Grey earthy limestone	1	0	332	6
	Soft dark sandy clay	4	0	336	6
	Grey limestone	0	6	337	0
	Dark grey clay	7	6	344	6
	Grey limestone	0	6	345	0
	Pale grey limy clay with a few hard calcareous bands; *Quenstedtoceras*				

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		Thickness. Ft.	in.	Depth. Ft.	in.
Oxford Clay 199 ft. 5 in.	*sp.* (finely ribbed) at 350 ft., *Eboraciceras ordinarium*? (Bean-Leck.) at 382 ft., and *Grammatodon concinnus* (Phill.)...	61	0	406	0
	Greenish and brownish-green sandy clay	39	0	445	0
	Pale fine grained limestone	1	0	446	0
	Soft brownish clay	8	3	454	3
	Smooth pale grey claystone	1	9	456	0
	Hard brownish shelly clay with thin bands of earthy limestone; *Cosmoceras stutchburii* (Pratt)	1	3	457	3
	Soft dark grey finely micaceous clay with a hard limy band at base; *Nuculana phillipsi* (Mor.), *Cosmoceras jason* (Rein.), and *C. stutchburii* (Pratt)	17	9	475	0
	Dark clayey sand, estimated thickness	3	0	478	0
	Brownish-grey sandy marl with *Gryphaea sp.*, *Pseudomonotis sp.* and *Cosmoceras sp.*	1	6	479	6
	Unconformity.				
Cornbrash? and Forest Marble 10 ft.	Hard bluish-grey non-oolitic limestone	2	0	481	6
	Dark shelly clay with *Ostrea sowerbyi* Morr. & Lyc.	0	6	482	0
	Hard bluish-grey limestone earthy in places	3	3	485	3
	Black and greenish-black shelly clay with a thin band of grey limestone; Lignite etc.	4	3	489	6
	Unconformity.				
Middle Lias 38½ ft.	Soft greenish sandy marl with a greenish gritty band and knobs of grey limestone	2	6	492	0
	Green tinged marly limestone with brown rusty specks, and a fragment (pebble?) of brownish-grey oolitic limestone. *Belemnites sp.*	1	6	493	6
	Soft grey micaceous sandy clay, green-tinged at top. At base, clay is hard and contains pebble-like concretions. *Lima pectinoides* J. Sow., *Cardinia sp.* and *Unicardium*?	9	6	503	0
	Smooth grey clay with a 4-inch band of brown limestone; *Amaltheus sp.* at 318 ft....	25	0	528	0
Lower Lias 142 feet	Dark grey shelly micaceous clay with thin limestone bands. *Aegoceras* cf. *lataecosta* (J. de C. Sow.) at 530 ft.	23	8	551	8
	Bluish-grey shelly limestone, with a thin clayey band	2	4	554	0
	Soft black clay with several thin bands of clayey limestone; *Nuculana sp.* (B.)	41	0	595	0
	No cores between 595 feet and 634 feet [said to be clay]...	39	0	634	0
	Black clay	0	6	634	6

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	Thickness. Ft.	in.	Depth. Ft.	in.
No cores between 634½ feet and 644 feet [clay]	9	6	644	0
Dark grey earthy limestone with *Rhynchonella* cf. *rostellata* (Quenst.) ...	2	0	646	0
Black clay with numerous specimens of *Nuculana sp.* (B.)...	24	0	670	0

Bottom of boring 670 feet.

Notes on the Cretaceous and Jurassic Rocks.

Lower Chalk. The lower part of this subdivision was passed through in the Severals House boring, and the details set forth in the section represent practically all the information that could be gleaned from a study of the cores. Towards the base of the Chalk, the marl is sandy and glauconitic as in the Stoke Ferry boring,[1] but no phosphatic nodules were found. The lower beds yielded specimens of *Ostrea canaliculata* (J. Sow.).

Gault. It is well known that the Gault undergoes marked changes in lithological characters and in thickness in passing northwards under the alluvium of the Fenland. Recently,[2] it has been pointed out that these changes are due to the fact that the Upper Gault has overlapped the Lower Gault. The Upper Gault is seen to become thinner and to rest unconformably on various members of the Lower Greensand when traced northwards to Hunstanton, where it forms a major part of the " Red Chalk." The transgression appears to have been accompanied by considerable erosion of the underlying beds, and as noted in the Methwold and Severals House borings, only a remnant of the basement beds of the Sandringham Sands is present at these localities. This does not necessarily imply that the erosion at the time of the Upper Gault transgression was responsible for the whole of this denudation of the Lower Greensand and the Lower Gault. It is highly probable that much of the Sandringham Sands had already been removed prior to the deposition of the Mammillatus Bed since this bed and associated sands are found to rest non-sequentially on a horizon low down in the Sandringham Sands in another boring to the north, a record of which has not yet been published. In the result, the great bulk, if not the whole of the Lower Cretaceous series of North Norfolk and of Lincolnshire, is absent in this district. The evidence of the borings, here described, confirms the statement made elsewhere,[3] that the Lower Gault and Mammillatus Bed of West Dereham is an isolated occurrence.

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[1] A. J. Jukes-Browne and W. Hill, ' On the lower part of the Upper Cretaceous series in West Suffolk and Norfolk,' *Quart. Journ. Geol. Soc.*, vol. xliii, 1887, p. 556.

[2] F. L. Kitchin and J. Pringle, ' On the Overlap of the Upper Gault in England and on the " Red Chalk " of the Eastern Counties,' *Geol. Mag.*, vol. lix, 1922, pp. 156–166, 194–200.

[3] *Op. cit.*, pp. 166, 199.

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In the Severals House boring the Lower Chalk passes down imperceptibly into the Upper Gault. The clay, which becomes nearly white after exposure, yields amongst other fossils, *Inoceramus sulcatus* Park. This shell is characteristic of Beds VIII and IX of Folkestone, and has been found at various localities along the outcrop to the north of West Dereham. Unfortunately, the downward range of the shell could not be tested in this boring as the clay, which contains abundant small chalk-white pellets in the lowest 30 feet, was so fragile that few cores were secured. A similar bed at the base of the Gault was passed through in the Methwold boring, but no attempt was made to secure a core. The thickness of the Upper Gault in the Severals House section is almost the same as that of the Gault recorded in a boring at Stoke Ferry.[1]

Lower Greensand. The beds referred to this formation are identical with those forming the basement beds of the Sandringham Sands at the outcrop around North Runcton Church,[2] and passed through in many of the borings made in search of oil-shale in the area lying between the Wissey and the Gaywood rivers.[3] The numerous black phosphatic nodules which are incorporated in the basement-beds appear to have been derived from the underlying Kimmeridge Clay. Some of them show obscure traces of ammonites. Iron pyrites is abundant in the matrix of the lowest layer of the sand. These nodules are not sandy, and in this respect differ from the phosphatized arenaceous nodules found in the Mammillatus Bed at West Dereham and elsewhere.[4]

Kimmeridge Clay. This formation was penetrated in each of the three borings, but its full thickness was only proved in the Methwold and Severals House sections. It consists mainly of dark clays with a few bands of grey argillaceous limestone and brown and greenish-brown oil-shales. These oil-shales are best developed in the upper part of the series. The Kimmeridge Clay of this district as exhibited in the cores of these borings is remarkably thin when contrasted with the thickness of the formation as exposed in the type area of Dorset, where it is estimated to be between 1,100 and 1,300 feet thick north of Weymouth.[5] The marked thinness of the formation appears to to have been the result of slow deposition and not to be due to the non-representation of beds through the existence of non-

[1] W. Whitaker, 'The Water Supply of Norfolk' (*Mem. Geol. Surv.*), 1921, p. 121.

[2] 'The Geology of South Western Norfolk and of North Cambridgeshire' (*Mem. Geol. Surv.*), 1892, p. 17.

[3] J. Pringle, 'Note on the Lower Greensand in the West Bilney borehole, Norfolk,' in 'Summary of Progress of the Geological Survey for 1919' (*Mem. Geol. Surv.*), 1920, p. 65.

[4] 'The Cretaceous Rocks of Britain' (*Mem. Geol. Surv.*), vol. i, p. 298; *see also* J. J. H. Teall, 'The Potton and Wicken Phosphatic Deposits' (Sedgwick Prize Essay for 1873), 1875, pp. 20–22.

[5] 'On the Thicknesses of Strata in the Counties of England and Wales' (*Mem. Geol. Surv.*), 1916, p. 49.

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sequences. No stratal breaks were detected during the examination of the cores. Indeed, the Kimmeridge zonal sequence established by Salfeld,[1] and amplified later by Kitchin and Pringle[2], appears to be completely represented so far as could be tested, excepting part of the uppermost zone. It is highly probable that the ridge of Palæozoic rocks which lay to the eastwards was submerged, and did not contribute to the accumulation of sediment.

The condensed character of the sequence is clearly brought out by a number of facts of different values. Thus, the radial plates of the free-swimming crinoid, *Saccocoma*, which characterize the ' Blackstone ' of Kimmeridge Bay and the ' Main Bed ' of Corton, have a vertical range of 13 feet in the greatly expanded series in Dorset. In the borings here described this fossil is confined to a bed less than one foot thick. Similarly, the shells referred to *Involuticeras desmonotus* (Oppel), which are found elsewhere in great abundance in the lower part of the Zone of *Rasenia mutabilis*, occupy an exceedingly narrow band in the cores of the Methwold and Severals House borings. Again, evidence of slow accumulation of sediment is to be found in the marked absence of large uncrushed shells and in the great abundance of bivalve-shells of small dimensions, such as *Lucina minuscula* Blake and several species of *Astarte*, while on some levels the shales are characterized by layers of fine ' shell-dust,' consisting mainly of opalescent fragments of ammonite shells which had broken down before entombment had taken place.

It is highly probable that the basement-bed of the Sandringham Sands rests on a level within the lower part of the Pallasianus Zone in the Methwold and Severals House borings. The clay passed through between the depths of 103 feet and 107 feet in the Severals House section yielded fragments of a ' *Perisphinctes* ' which is closely comparable with certain shells commonly found in the lower part of this zone in Dorset. Better preserved ammonites obtained from the cores of a boring near King's Lynn give weighty support to this correlation. It is of interest to note, therefore, that the Sandringham Sands in Norfolk rest unconformably on the same horizon as that on which the Spilsby Sandstone is found in the Donnington Borehole in Lincolnshire.[3]

The lower part of the underlying Pseudovirgatites zone is conspicuously represented in each of the borings by the subzone of *Saccocoma*. The pyritized radial plates of this free-swimming crinoid were found in abundance, and in the Severals House section it was noted that the vertical range of the genus was

[1] H. Salfeld, ' Certain Upper Jurassic Strata of England,' *Quart. Journ. Geol. Soc.*, vol. lxix, 1913, pp. 423–432.

[2] G. W. Lamplugh, F. L. Kitchin, and J. Pringle, ' The Concealed Mesozoic Rocks in Kent ' (*Mem. Geol. Surv.*), 1923, pl. ii.

[3] J. Pringle, ' Palæontological notes on the Donnington Borehole of 1917,' in ' Summary of Progress of the Geological Survey for 1918 ' (*Mem. Geol. Surv.*), 1919, pp. 50–52.

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8 inches. In the Methwold and Decoy borings it characterized a band of shale about one foot thick. *Saccocoma* also occurs abundantly in the so-called Puny Drain shales of the Setch district, and it has proved to be a useful datum-guide in the majority of the borings in the Kimmeridge Clay throughout Norfolk. The other constituents of the fauna present in abundance are *Lucina minuscula* Blake, *Ostrea bononiae* Sauvage, and fish-remains. The Zone of *Virgatites* is not well defined in the Decoy and Methwold sections, but at Severals House, where the base of the zone is taken at a cement-stone penetrated at a depth of 132 feet, it is 10 feet in thickness. This rock-band is clearly on the same stratigraphical horizon as the Yellow Ledge of Kimmeridge Bay, where it forms the base of the Virgatites Zone and the top of the Zone of *Gravesia gravesi*. In Norfolk, as in Dorset, the cement-stone marks the limit of the upward range of *Exogyra virgula* (Defr.), while the overlying shales contain early forms of *Modiola autissiodorensis* (Cott.). The lower limit of the Gravesia Zones was not determined, but it must lie between the depths of 143 feet and 162 feet in the Severals House section. At 162 feet from the surface, the Zone of *Aulacostephanus pseudomutabilis* is indicated by the presence of *Amoeboceras krausei* (Salfeld). This ammonite is frequently found in association with *Aulacostephanus eudoxus* (d'Orb.), and appears to be closely related to certain shells formerly, though wrongly, referred to *Ammonites kappfi* Oppel from this zone in Kimmeridge Bay. The clay which probably represents the lower Aulacostephanus Zone failed to yield ammonites in any of the borings.

The Zone of *Rasenia mutabilis* is well shown in all of the sections by the occurrence of *Involuticeras desmonotus* (Oppel) and other closely allied forms. These shells are also characteristic of the lowest beds of the Kimmeridge Clay in the Roslyn Hill pit, near Ely. In the Dover section, similar species occur at a height of about 45 feet above the top of the Corallian.[1] In south-west Norfolk, in a more attenuated sequence, they are found in abundance about 18 feet above the base of the Kimmeridge Clay, and have proved to be a most useful datum-guide in all of the sections. The beds which probably represent the underlying Zone of *Rasenia cymodoce* did not yield any ammonites. Numerous specimens of *Rasenia stephanoides* (Oppel) have, however, been collected from the clays of this zone in several borings near King's Lynn.

In the Methwold and Severals House sections the grey limy clay at the base of the formation contained fragments of smooth ammonites, which, Mr. S. S. Buckman suggests, might be referred to the genus *Pictonia*. Although, owing to the size of the cores, the fragments are too small for us to be certain of this identification, it is thought likely that the bed falls within the Pictonia Zone.

[1] G. W. Lamplugh and F. L. Kitchin, 'On the Mesozoic Rocks in some of the Coal Explorations in Kent' (*Mem. Geol. Surv.*), 1911, p. 116.

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Corallian. As might be expected, the sequence of the Corallian rocks is nearly identical in the two borings. The formation is mainly represented by clays of Ampthill type, containing in the lower portion several thin bands of smooth compact limestone. In the Severals House section a soft black shelly clay, which was absent in the Methwold boring, is shown as forming the top of the Corallian; it is possible, however, that this is due to a reversal of core, a matter of common occurrence during boring-operations.

At about 24 feet below the top of the formation in both borings, the clays yielded several specimens of *Amoeboceras serratum* (J. Sow.), which indicate the Zone of *Perisphinctes decipiens* of Salfeld's classification. In the Methwold boring the ammonites were accompanied by *Protocardia delibata* (de Lor.), which is a common shell on horizons in France corresponding with our uppermost Corallian and Lower Kimmeridge Clay. The thin bands of limestone in the lower part of the formation probably occupy a position corresponding to that of the Elsworth Rock, but they do not show any of the characteristic features of that well-known rock-band. In the clay at the base of the formation in the Severals House section, a young specimen of *Cardioceras* was found at the depth of 277 feet. This ammonite, although it remains specifically undetermined, strongly suggests the presence of the Scarburgense Zone of Mr. S. S. Buckman's classification.[1] This zone, which, at least in part, replaces the 'Pre-*cordatum* Zone' of Mr. Buckman, is now assigned by him to the Argovian stage when that name is employed to comprise the strata which are distinguished by the presence of *Cardioceras*. The thickness of the Corallian in the Methwold and Severals House sections is nearly the same as that of the corresponding beds proved in the Stretham boring.[2]

Oxford Clay. Lithologically, the beds comprised under this heading fall into two parts: an upper, consisting mainly of black and grey clays with subordinate bands of limestone, and a lower, which is largely made up of green-tinged brownish-grey clays and sandy marls. The higher beds were poorly fossiliferous, and yielded only a few fossils mostly in a fragmentary condition. These included several unidentified species of *Quenstedtoceras*, one of which was found on a horizon about 31 feet below the top of the formation in the Methwold section. The lower beds, on the other hand, were highly fossiliferous, and probably fall wholly within the Ornatus subdivision of the Oxford Clay, in the broad sense. The lithological characters of the clays are closely similar to those of the zone as shown in the Kentish borings.

In the absence of determinable fossils of zonal significance, it is assumed that the Zone of *Quenstedtoceras mariae* is represented

[1] *See* 'The Geology of the Country between Whitby and Scarborough' (*Mem. Geol. Surv.*), 1915, pp. 60 and 87.

[2] T. Roberts, 'The Jurassic Rocks of Cambridge,' 1892, pp. 23, 24, 47, 65.

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by some portion of the higher clays. In most borings fossils prove to be somewhat rare in these upper beds of the Oxford Clay. The underlying Renggeri Zone, however, is indicated in the Methwold and Severals House sections. The specimen assigned to *Quenstedtoceras* cf. *lamberti* (J. Sow.), which was kindly examined by Mr. S. S. Buckman, was found at the depth of 337 feet in the Methwold boring, and it is closely comparable with similar shells from the Renggeri Zone in the Ludgershall railway-cutting, near Bicester. The shell is preserved in bright pyrites. The same horizon is shown in the Severals House boring by the occurrence of *Eboraciceras ordinarium*? (Bean-Leck.) at the depth of 382 feet, where it is associated with *Grammatodon concinnus* (Phill.).

The top of the Ornatus Beds was reached at about the depth of 353½ feet in the Methwold section, but the boring stopped before proving the full thickness of the subdivision. At Severals House these beds were entered at the depth of 406 feet, and were found to be 73½ feet thick. They were highly fossiliferous, and some of the more important species are given in the detailed sections set forth on p. 129. In the lowest bed of this subdivision in the Severals House borehole, a fragment of a *Cosmoceras* having some resemblance to *C. elizabethae* (Pratt) was found. It is likely, therefore, that the Kellaways Rock has no representation, since the underlying rock-band is probably of Cornbrash age. All of the formations which remain to be described were passed through in the Severals House boring.

Cornbrash and Forest Marble. The 2-foot band of hard grey non-oolitic limestone penetrated at the depth of 479½ feet, is referred doubtfully to the Cornbrash in the absence of characteristic fossils. The rock-band compares closely with a similar limestone containing *Macrocephalites* in the Westbury boring.[1] The lithological features of the Forest Marble are identical with those which characterize the formation in its underground range in Kent, and the greenish-black colour of some of the lower clays is similar to that displayed by a portion of the corresponding beds in the Blackthorn Hill railway-cutting, near Bicester. The following fossils, mostly in a poor state of preservation, were collected :—Lignite, *Rhynchonella sp.*, *Astarte sp.*, *Modiola sp.*, *Ostrea sowerbyi* Morris and Lycett, and *Pecten (Chlamys) vagans?* J. de C. Sow. No pebbles were found at the base, which rests on a fresh unweathered surface of Middle Lias. Although the existence of a non-sequence between the Forest Marble and the Great Oolite in the railway-cuttings near Bicester has been pointed out,[2] this appears to be the first instance in

[1] J. Pringle, ' On a boring for coal at Westbury, Wiltshire,' in ' Summary of Progress for 1921 ' (*Mem. Geol. Surv.*), 1922, p. 147.

[2] A. M. Davies and J. Pringle, ' Two deep borings at Calvert Station,' *Quart. Journ. Geol. Soc.*, vol. lxix, 1913, p. 316.

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England where the Forest Marble is found to rest directly on the Middle Lias.

Lias. The green-tinged marly limestone entered at the depth of 489½ feet in the Severals House boring clearly belongs to the Marlstone of the Middle Lias. Specimens of the rock so closely resemble those taken from the lower part of this sub-division in the Folkestone boring[1] that they are only separable by means of their labels. The only fossils found were fragments of *Belemnites*. The underlying soft grey micaceous clay, which possibly represents the upper part of the Margaritatus Zone, was more highly fossiliferous, and yielded *Cardinia sp.*, *Gryphaea ?*, *Lima pectinoides* J. Sow., *Protocardia sp.* and *Unicardium ?*. The thick bed of soft grey clay at the base contained several specimens of a juvenile form of *Amaltheus* at the depth of 518 feet. Mr. S. S. Buckman, who has examined the shells, states that they indicate the lowest Middle Lias clays as developed just above the Three Tiers at Charmouth in Dorset.

Owing to mishaps during boring operations, the complete sequence of the Lower Lias clays was not displayed in the cores. The beds which were seen, however, yielded the following characteristic fossils :—

Depth in feet.	
531–532	Pentacrinus sp. [columnals]
645	Rhynchonella *cf.* rostellata (*Quenst.*)
647	Astarte sp.
650	Grammatodon intermedius (*Simp.*)
504	Gryphaea *cf.* cymbium (*Lam.*)
552½	Lima pectinoides *J. Sow.*
560, 647	Nuculana sp. (B.)
530, 532, 550 560, 564	,, sp.
552½	Ostrea sp.
532, 563, 650	Pecten (Syncyclonema) liasianus *Nyst*
531, 560, 647	Protocardia sp.
532, 560, 645	Pteria (Oxytoma) sp.
563	Actaeonina *cf.* ilminsterensis *Moore*
550	Chemnitzia sp.
530	Aegoceras *cf.* lataecosta (*J. de C. Sow.*)
647	Tragophylloceras ?

The occurrence of the ammonite which is brought into comparison with *Aegoceras lataecosta* (J. de C. Sow.) proves the presence of the Capricornus Zone. The shell is well preserved, and was found in a thin band of limestone, 2 feet below the top of the sub-division. It is not known at what depth the Jamesoni Beds was entered, owing to the absence of cores, but at 644 feet a dark grey earthy limestone, yielding numerous specimens of *Rhynchonella*, appears to be well within the zone. The shells are identical with the forms brought into comparison with *Rhynchonella rostellata* (Quenst.), found between the depths of 1815 feet and 1818 feet at Brabourne.[2] Like the Kentish

[1] G. W. Lamplugh, F. L. Kitchin, and J. Pringle, ' On the Concealed Mesozoic Rocks in Kent ' (*Mem. Geol. Surv.*), 1923, p. 30.

[2] G. W. Lamplugh and F. L. Kitchin, ' On the Mesozoic Rocks in some of the Coal Explorations in Kent ' (*Mem. Geol. Surv.*), 1911, p. 176.

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specimens, they are smooth until the adult stage is well advanced, when plications are developed. At Severals House the shells occur in some profusion on a level about the depth of 645 feet. *Nuculana sp.* (B) is another species of importance which is also characteristic of the Lower Lias of Brabourne and other borings in Kent, where, as in Norfolk, it ranges from the Jamesoni Beds up to the Capricornus Zone. Its resemblance to *Nuculana quenstedti* (Tate) has already been commented on,[1] but the shell awaits further description.

It is impossible to state how much more of the Lower Lias remained to be bored through before reaching older formations; but comparing the thickness of the Lias with that of the Middle and Upper Jurassic rocks proved in the area, it will be seen that sedimentation was proceeding more rapidly during the accumulation of the Lias than throughout the periods which followed. As already pointed out, so far as the clays of the Lower Lias have been penetrated, they do not indicate the near proximity of a shore-line. It is possible that the Jamesoni Beds may rest unconformably on older rocks in this area, as at Brabourne and Dover in Kent; but further borings alone can settle the question.

APPENDIX II

On the Ammonite Horizons of the Gault and Contiguous Deposits

By L. F. Spath, D.Sc.

By permission of the Director of the Geological Survey the writer was enabled to incorporate in his account of an 'Excursion to Folkestone,'[2] some of the results of an examination of the well-known Gault locality of East Wear Bay, undertaken on behalf of the Survey. In addition to reporting on recent changes in the classical cliff-section, the writer collected numerous fossils, especially from the rather barren upper beds XI–XIII, Mr. S. W. Hester rendering valuable assistance. This allowed of a more detailed subdivision of the upper sixty feet, or more than half the total thickness, of Gault, misleadingly grouped by Price[3] as one 'Zone of *A. rostratus*,' whilst modern French authors[4] still include in this one 'Zone à *Mortoniceras inflatum*' the whole of the Upper Gault. Price had named nine out of his eleven 'zones' after ammonites, but six of these nine zonal ammonites were wrongly identified and Jukes-Browne's later account[5] was equally unsatisfactory. The records of such notorious species as *Hoplites 'interruptus,' raulinianus, auritus*

[1] *Op. cit.*, p. 175.

[2] *Proc. Geol. Assoc.*, vol. xxxiv, 1923, pp. 70–76.

[3] 'The Gault,' 1879, table on p. 12.

[4] See Tomitch, 'Contrib. Connaiss. Étage Albien,' &c. (Notes Provençales du Dr. Guébhard, No. vi, St.-Vallier-de-Thiey). Le Mans, 1918.

[5] 'Cret. Rocks of Britain. I. The Gault and Upper Greensand' (*Mem. Geol. Surv.*), 1900.

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and *denarius* are generally useless on account of the confusion of externally similar forms belonging to different horizons in the Gault. A table prepared by the writer and included in the above Excursion Report gives a new subdivision of the Albian age and a correlation of its zones with the various beds found at Folkestone.

The occurrence of '*Anahoplites*' of the *catillus*-group in the lower part (where *Anisoceras* is particularly common) of bed XI, already recorded by Dr. Kitchin and Mr. Pringle in this Summary[1] was confirmed, also the absence of true *Turrilites*; and of special interest was the recognition of the succession in time of the various dipoloceratid genera, in view of recent criticisms by Stieler.[2] The writer's contention[3] that the genus proposed for the *rostratus*-group may require further subdivision was justified and Stieler's statement[4] that comprehensive interpretation of species is particularly necessary in the case of the *Inflaticerata* can only be ascribed to limited knowledge of the richness and variety of the Gault fauna. It may be useful to state briefly the vertical distribution, as known at present, of the keeled ammonites of the Gault (*Dipoloceratidae*) and of the various Folkestone *Hoplites*, so abundantly represented in all collections.

Eight dipoloceratid genera are known to occur, but two others namely, *Oxytropidoceras* and *Falloticeras*, with the lyelliceratid genera *Brancoceras*, *Tegoceras*, and *Raulinicera*s, have not yet been found in this country. The earliest is *Mojsisovicsia* (bed IV) followed by *Dipoloceras* (beds V–VIII). The Upper Gault descendants of the latter appear to have the following ranges :—

Elobiceras	Beds IX & X
Hysteroceras	„ VIII to XI
Prohysteroceras	„ IX to XI
Inflaticeras	„ XI & XII
Neoharpoceras	„ XI & XII
Neokentroceras ?	Bed XIII

The hoplitid genera have been provisionally classed into seven groups, of which only four are at present named. The group of '*Hoplites*' *puzosianus* and '*H.*' *raulinianus* (d'Orbigny) is restricted[5] to bed Ia; *Hoplites* s.s. (*dentatus*-group) to beds I to III. The latter gives rise to two stocks that persist to bed XI, namely *Anahoplites*, Hyatt emend. Spath, comprising the groups of *A. splendens* and *A. tethydis*, connected by innumerable transitions, and the group of '*Hoplites*' *lautus* and '*H.*' *tuberculatus*. The *tethydis*-group leads to *Ammonites denarius* and *A. auritus*,[6] wrongly compared by Kilian and Sinzow to *Saynella* and confined

[1] 'Summary of Progress for 1920' (*Mem. Geol. Surv.*), 1921, p. 62.

[2] 'Anomale Münd. b. Inflaticeraten,' *Neues Jahrb. f. Min.*, etc., Beil., Bd. xlvii, 1922, p. 339. 'Üb. Gault- u. Cenoman-Ammon. a. d. Cenoman d. Cap Blanc Nez,' *Neues Jahrb. für Min.*, etc., 1922, Band ii, Heft 2, p. 34.

[3] 'On Cretaceous Ammonoidea from Angola,' *Trans. Roy. Soc. Edinb.*, vol. liii, pt. 1, No. 6, 1922, p. 97.

[4] *Loc. cit.* (1922, 'Anomale Münd.'), p. 340.

[5] '*Hoplites*' in the Excursion Report, *loc. cit.*, p. 74.

[6] '*Anahoplites*,' *ib.*, p. 76.

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to beds X and XI; the *denarius*-stock again leads to *Pleurohoplites* of bed XIII. The *lautus-tuberculatus*-type is continued in *Hyphoplites* of the *dispar*-zone and the Lower Cenomanian.

Other information not incorporated in the Excursion Report was obtained from some inland sections near Folkestone. In the Broadmead sand-pit at Cheriton the following sequence was shown :—

		Ft.	in.
	Soil	1	0
dentatus-zone	Clayey Greensand with *Hoplites dentatus*, &c.	2	0
	Line of 'Sulphur Nodules' without fossils	0	4
Non-sequence			
mammillatus-zone	Greensand	1	6
	Upper line of nodules with *Douvilleiceras monile* (J. Sow.), *D.* cf. *mammillatum* (Schloth.), *Beudanticeras ligatum* (Newt. and Jukes-Browne) and fossil wood	0	3
	Yellow sand	1	6
	Lower line of iron-stained nodules with *Douvilleiceras monile*, *Beudanticeras ligatum*, *Ostrea sp.*, *Pecten sp.*	0	3
Folkestone Sands	Silver-sand, without fossils	10–12 ft.	

The absence from the Folkestone area of the *regularis*-fauna has already been noticed by Dr. Kitchin in this Summary.[1]

In the shallow Broadmead clay-pit, belonging to the same works (Lord Radnor's), no fresh section was visible, and yellowish clays, yielding (loose) fossils like '*Hoplites*' aff. *proboscideus* (J. Sow.) '*H.*' *lautus* (J. Sow.), and *Anahoplites sp. nov.*, presumably from the top of the Lower Gault, were covered by chalky hill-wash.

Similarly the equally shallow Cheriton Pit, though mostly in lower (blue) Gault clay, did not offer a satisfactory, clean section, but both the yellowish Upper Gault (beds IX, X, and basal XI) and the blue Lower Gault (beds II or III to VIII) were exposed in a very clear 35–40 ft. section in the pit of the Brick and Tile Co. at Elenden Gardens, Cheriton. The beds are not uniform in colour or lithological character across the face of the pit, and at the western end, the top includes a greater portion of bed XI, below a foot or so of surface-soil, than at the eastern end, where the summit is low down in XI. Also, the hard bands in bed IX are very irregular, as seen on the face of the pit; but the 15–18 ft. of Upper Gault, to within a foot of the base of bed IX, is of a very distinctive yellow colour, sharply marked off from about twenty feet of more or less uniform, dark blue, Lower Gault, with irregular patches rather than bands weathering to a lighter blue. The light buff clay of bed III ('crab-bed') that forms a conspicuous, precipitous, seam in the cliff-section at Copt Point, was not distinct at the base of the pit; and the 'mottled bed' (VI) was not clearly recognizable. Conversely at 2, 6, and

[1] 'Summary of Progress for 1919' (*Mem. Geol. Surv.*), 1920, p. 45.

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10 feet up, nodular bands were seen, but could not be correlated exactly with those, for instance, of bed IV at Copt Point. According to the foreman, the base of the Gault clay was met with 12 ft. below the floor of the pit. Some new species of *Hoplites* and *Anahoplites*, peculiar to beds II and III on the coast, were discovered in the lowest five feet, associated with *Hamites attenuatus* J. Sowerby; but no detailed zonal collecting was done to ascertain the changes in the various beds and their apparent thickening in the short distance from the coast.

It may be useful to discuss the less local aspects of the Albian succession. Collecting in lower beds, and especially in the Gault of Wiltshire and other important areas, has not yet been done with the detail necessary to enable the writer to place, for example, the *Lyelliceras* fauna, absent from Folkestone, and almost certainly fairly low in the Lower Gault. The *benettianus* and *inaequinodus* faunas of Wiltshire and North Dorset are also at present only assumed to have existed during the time-interval that preceded the deposition, on the sandy substratum of the *mammillatus*-zone, of the lowest clay-beds at Folkestone.

The uppermost and lowest beds of the Albian, and the relations of their ammonite-faunas to those of the contiguous formations require special consideration.

A fauna characterized by species of *Stoliczkaia* and by large, inflated forms of *Pleurohoplites* (*dispar*-zone) succeeds an earlier *Pleurohoplites*-fauna with small examples of *Pl. studeri* and the compressed forms of the type of *Pl. renauxianus* (d'Orbigny). The later (= *dispar*) fauna is found in North Dorset ('Upper Greensand') and is included in the phosphate-bed of Cambridge, in which deposit, however, the earlier *Pleurohoplites* and even the *aequatorialis* faunas (of the 'Chert' and 'Malm' Series of the Upper Greensand) are also represented.[1] It is uncertain to which of these three upper Albian zones must be referred the Mediterranean elements of the Cambridge Greensand, namely, *Phylloceras*, *Lytoceras* (*Gaudryceras*), *Tetragonites*, and *Desmoceras* ('*Latidorsella*'). It is also interesting to note that the lytoceratid genus *Kossmatella* has not yet been discovered in this country. It ranges through a number of horizons in Mediterranean deposits, but is referred by Jacob[2] to the '*dentatus*' or even '*tardefurcata*' zones, though other authors have recorded it from the Upper Albian. In the Drôme[3] some of its representatives are associated with *Phylloceras sp.*, *Tetragonites timotheanus*

[1] The forty feet or so of unfossiliferous clays below the phosphate-bed appear to correspond mainly to the *auritus*-zone of Folkestone, and the 'abundance of Lower Gault fossils in the Cambridge Greensand' ('Geology in the Field,' 1909, p. 151) has no real existence.

[2] 'Ammon. Crét. Moyen,' etc., *Mém. Soc. Géol. France, Pal.*, No. 38, 1907, pp. 21–3. W. Kilian ('Crét. Infér. France,' *Mém. Carte Géol. France*, 1920, p. 27) records *Kossmatella chabaudi* (Fallot) from the Lower Albian, as well as '*Gaudryceras sacya* (Stoliczka)' which is almost certainly due to misidentification.

[3] E. Fallot. 'Étude Géol. Étages Moyens & Supér. Terrain Crét. S.E. France,' *Bibl. École Hautes Études, Sect. Sci. Nat.*, xxx, 1, 1885, p. 153.

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(Pictet), and *Desmoceras latidorsatum* (Michelin), three Cambridge Greensand types of little value for exact correlation; but this *Kossmatella*-bed is followed by shales with *Gaudryceras dozei* (Fallot) and undoubted Cenomanian *Turrilites*, probably corresponding to the *martimpreyi* beds of Aumale in Algeria [1] At Ventnor, where *Pleurohoplites renauxianus* occurs, though *Stoliczkaia* has not yet been found, such supposed Lower Chalk species as *Gaudryceras leptonema* (Sharpe), *Phylloceras* '*velledae*' (Sharpe, *pars*, *non* Michelin,= *Ph. seresitense* Pervinquière) and *Puzosia octosulcata* (Sharpe) have been collected. There is little difference between the chalky matrix of these and that of the Albian *Pleurohoplites*. But Sharpe's *A. leptonema* is unlike any described species of Albian *Gaudryceras*, except possibly a Japanese *Lytoceras sp.* of uncertain horizon, figured by Yokoyama[2] and compared to *Gaudryceras sacya* (Forbes); and a doubtful example of *G. leptonema* from Devon recorded by Jukes-Browne[3] is associated with a true Cenomanian fauna.

Some work, then, remains to be done with regard to the exact horizon of several of these Mediterranean elements; but it may be mentioned that only one Cambridge Greensand ammonite, namely, *Puzosia sp. nov.* = *A. mayorianus* Seeley [*non* d'Orbigny], preserved indifferently in black or brown phosphate, has so far been found also in the Cenomanian (Chloritic Marl) of Warminster and Bonchurch. It will be readily admitted that a long-lived desmoceratid like *Puzosia* has no zonal value.

In the earliest British Cenomanian deposits *Schloenbachia*[4] is associated with *Mantelliceras couloni* (d'Orbigny) and *M. martimpreyi* (Coquand) and allied species and with two new genera, both represented by unnamed Warminster species, namely, *Submantelliceras* gen. nov. (type: *Acanthoceras aumalense* [Coquand] Pervinquière: 'Ammon. Crét. Algér.,' *Mém. Soc. Géol. France, Pal.*, (42), 1910, p. 42, pl. iv, fig. 11) and *Euhystrichoceras* gen. nov. (type: *Mortoniceras? nicaisi* [Coquand] Pervinquière, *ibid.*, p. 65, pl. vi, figs. 18, 19). The zone of *Pecten asper* has, of course, long been found to be valueless, and Barrois's 'Zone of *A.* [*Sharpeiceras*] *laticlavius*,' according to Stieler,[5] at the type locality Cap Blanc Nez contains not only derived Lower and Upper Gault fossils, but *Mantelliceras* and *Calycoceras* from well above the base of the Cenomanian. How the occurrence in this supposed Cenomanian bed of, for instance,

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[1] L. Pervinquière. 'Ammon. Crét. Algér.,' *Mém. Soc. Géol. France, Pal.*, vol. xvii, 1910, Mém. No. 42, p. 77.

[2] 'Verst. Japan. Kreide,' *Palæontogr.*, vol. xxxvi, 1890, p. 180, pl. xix, figs. 3a, b.

[3] In Jukes-Browne and Hill. *Quart. Journ. Geol. Soc.*, vol. lii, 1896, p. 163.

[4] Stieler's (*loc. cit.*, 1922, 'Blanc Nez,' p. 30) identification of *Schloenbachia intermedia* (Mantell) with *S. costata* (Sharpe) seems to show that some of the numerous British species of *Schloenbachia* are unknown on the Continent.

[5] *Ibid.*, pp. 25–26.

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a derived *Douvilleiceras mammillatum* can be reconciled with Stieler's[1] statement that at Cap Blanc Nez, the Gault 'in its complete development' is overlain conformably by the Cenomanian, the writer is at a loss to understand. So far as observations go the Cenomanian seems to be divisible into the following ammonite-horizons :—

Upper Cenomanian	Metoicoceras pontieri
(Acanthoceratan)	Acanthoceras cenomanense
[*subglobosus*-zone of authors]	Calycoceras baylei
Lower Cenomanian	Euomphaloceras euomphalum[2]
(Schloenbachian)	Hyphoplites falcatus
[*varians*-zone of authors]	Mantelliceras martimpreyi

Better species may be found for these horizons when the necessary field-work has been done, and the lower three especially, forming the *varians*-zone of most authors, should yield distinctive species of the common genus *Schloenbachia*. The tuberculate early forms of *Calycoceras* of the *falcatus*-zone lead to two developments that flourished before the costate *Calycoceras* (*baylei*-group) and *Acanthoceras* s.s. became dominant. One (*Eucalycoceras* gen. nov.) includes '*Acanthoceras*' *newboldi* Kossmat and its var. *spinosa*, better renamed *Eucalycoceras spinosum*, '*Ac.*' *choffati* and '*Ac.*' *gothicum* Kossmat and others, and as type may be taken *Eucalycoceras pentagonum* Jukes-Browne (*Quart. Journ. Geol. Soc.*, vol. lii, 1896, pl. v, figs. 1, 1a). The other stock (*Protacanthoceras* gen. nov.) via *P. triserialis* (J. de C. Sow.) leads to *P. compressum* (Jukes-Browne) and *P. bunburianum* (Sharpe) (genotype, *loc. cit.*, 1854, p. 25, pl. ix, figs. 3a–c), and several unnamed forms. *P. hippocastanum* (J. de C. Sow.) is transitional from this to the typical, later, *Acanthoceras*, occurring chiefly in the *baylei*-zone, with flattened forms of the type of *Ac. vicinale* (Stoliczka) in the next higher zone. It may be added that *A. rhotomagense* (Defrance MS.)[3] is the genotype of *Acanthoceras* and Hyatt's *Metacanthoplites* must be rejected; whilst for *A. deverianus* d'Orbigny ('Pal. Franç., Terr. Crét.,' i, 1841, p. 356, pl. cx), generally erroneously included in *Acanthoceras*, the new genus *Romaniceras* is proposed; and for *A. peltoceroides* Pavlow ('Argiles de Speeton,' 1892, p. 152, pl. xviii, fig. 21), also wrongly referred to *Acanthoceras*, the new genus *Parastieria*.

Now the interesting problem arises whether faunas with ammonites such as *Hypengonoceras warthi* in India or *Knemiceras*

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[1] *Ibid.*, p. 22.

[2] The new genus *Euomphaloceras* (type: *A. euomphalus*—Sharpe, 'Foss. Moll. Chalk,' pt. 2, 1854, p. 31, pl. xiii, fig. 4, *Palæontographical Society*; Brit. Mus., No. 50158) is here proposed for this stock, which has nothing to do with *Douvilleiceras*. Its suture-line resembles that of *Acanthoceras sussexense* and *A. cunningtoni*. (*See* Spath: 'Cret. Cephalop. from Zululand,' *Annals South African Mus.*, vol. xii, pt. vii, No. 16, 1921, p. 314.

[3] In Brongniart: 'Descr. Géol. des Environs de Paris,' 1822, p. 83, pl. iv, fig. 2. Sowerby's *A. rhotomagensis* ('Mineral Conchol.', 1826, vol. vi, p. 25, pl. 515, fig. 1, B.M. No. 43983a) is specifically distinct and may be renamed *Acanthoceras subflexuosum* sp. nov. The original of fig. 2 agrees with Mantell's *A. sussexensis*.

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uhligi in Portugal represent southern equivalents of our Upper Albian or Lower Cenomanian, or whether they existed during a time interval in which no deposits were laid down in north-western Europe. *Knemiceras uhligi*, of course, has been erroneously recorded from Lower Albian as well as Cenomanian strata; but in Portugal,[1] in the lower Bellasian zone I, it is associated with '*Schloenbachia inflata*, var. *lampasensis*' Choffat, which, though of somewhat unusual appearance, is probably related to some of the quadrituberculate species of *Inflaticeras* described by the writer from Angola.[2] In Tunis, *Knemiceras uhligi* occurs in beds classed by Pervinquière as Vraconnian, but including not only several horizons of the Upper Albian, but also undoubted Cenomanian fossils, *e.g.*, *Forbesiceras obtectum* (Sharpe) of the *falcatus*-zone.

In India, *Stoliczkaia* of the uppermost Albian and Lower Cenomanian is found, as well as *Mantelliceras*, *Sharpeiceras*, and *Forbesiceras*. It is thus fair to assume that dissimilar faunas here do not indicate deposits of different ages, even if detailed collecting in new areas may enable us to increase considerably the number of hemeræ here recognised. It is possible that the *euomphalus* and *falcatus* zones, on further research, may be found to be divisible into such a sequence as the following :—

Protacanthoceras compressum (*Jukes-Browne*)
Schloenbachia costata (*Sharpe*)
Forbesiceras sp. [aff. *complanatum* Mantell]
Calycoceras naviculare (*Sharpe*) [*non* Mantell]
Mantelliceras sp. [aff. *feraudianum* Sharpe, *non* d'Orb.]
Mantelliceras mantelli (*J. Sow.*)

But in India other forms would represent the same succession and at Aumale in Algeria neither the English nor the Indian zonal species may be traceable though the same horizons are clearly developed. Local non-sequences may have no relation to the absence of whole faunas. That in southern deposits just those horizons or ages[3] are missing that were preserved in north-western Europe, and vice versâ, is as little probable as that ammonites had a uniform world-wide distribution. *Hypengonoceras*, like the earlier *Engonoceras* and other Pseudoceratites, or like the persistent radical stocks *Phylloceratidae* and *Lytoceratidae* in general, did not penetrate into the areas of temporary transgressions, where the rapidly modifying derivatives of these two 'stenothermal' families enormously increase. The genus *Oxytropidoceras* (*roissyanus*-group), referred to above, is common in North-, Central-, and South-America, in addition to Mediterranean countries, and in South Africa it is associated with Dipoloceratids of the upper part of the Lower Gault. But Hoplitids which in Western Europe far outnumber *e.g. Oxytropidoceras* or *Lyelliceras*, are absent in these American and African deposits.

[1] P. Choffat. 'Faune Crét. Portug.,' I, 1886, p. 47. *Comm. Trav. géol. Portugal.*

[2] *Loc. cit.* (Angola, 1922), pp. 115–18.

[3] S. S. Buckman, 'Type Ammonites,' pt. xxxiv, 1922, p. 7.

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Mr. Buckman's[1] comparison, say, of the *transversarius*-fauna of Mediterranean countries with the *martelli*-fauna of England, without consideration of the ever-present *Sowerbyceras* and '*Haploceras*' on the one hand, and Cardioceratids on the other, that clearly demonstrate the limited horizontal distribution of certain ammonites, is undoubtedly open to criticism.

As regards the lower limit of the Albian, Ganz,[2] in 1912, placed the '*nodosocostatum*-zone' again in the Gargasian or Upper Aptian, but Kilian[3] in 1913, showed that Jacob and Stolley had been right in including the *nodosocostatum*-zone, or Clansayes horizon, in the Albian, and this classification is here adopted. Incidentally it may be remarked that Ganz also reviewed the history of the term Gault, as Jacob[4] had done in 1908, unfortunately equally unsuccessfully on account of incomplete knowledge of the English type-succession. It may suffice to point in this connexion to the curious mixture of Upper and Lower Gault forms that he records from his 'Lochwald Bed' (p. 121) or to the supposed occurrence in the Cenomanian of *Hysteroceras varicosum* (p. 129).

Of the lowest six subzones of the Albian, namely :—

tardefurcata-zone	*regularis* subzone
	milletianus ,,
	schrammeni ,,
nodosocostatum-zone	*jacobi* ,,
	trautscholdi ,,
	abichi ,,

none has been identified in the Folkestone Sands. Mr. W. J. Atkinson, of Hythe, to whom the writer is indebted for much information regarding local beds of the Lower Greensand, sent a photograph of what appears to be a large *Parahoplites* of Upper Aptian age, said to come from the uppermost part of the Folkestone Sands at Sandling Junction. On the other hand, *Parahoplites* (*Acanthoplites*?) *simmsi* (Forbes) from Hythe, greatly resembling *Acanthoplites aschiltaensis* (Anthula), is preserved in an ironstone that cannot be higher than the base of the Folkestone Sands, where Topley noticed a brown ferruginous sandstone with nodules in which Price[5] found 'two ammonites.' Again, Meyer[6] regarded the Nutfield Beds [with Upper Aptian *Parahoplites* and

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[1] 'Type Ammonites,' part xxxvii, 1922, p. 25.

[2] 'Stratigr. Mittl. Kreide, Ob. Helvet. Decken, N. Schweiz. Alp.,' *Neue Denkschr. Schweiz. Naturf. Gesellsch.*, vol. xlvii, 1912, p. 144.

[3] In Frech. 'Lethæa Geogn.,' vol. ii, Mesozoic., pt. iii, Kreide, i, Unterkreide, fasc. 3, 1913, p. 347.

[4] 'Études Pal. & Strat. sur la Partie Moy. d. Ter. Crét.,' *Trav. Lab. Géol. Univ. Grenoble*, vol. viii, 1908, p. 584.

[5] 'Excursion to Hythe, Sandgate and Folkestone,' pt. ii, *Proc. Geol. Assoc.*, vol. xiii, 1893, p. 148.

[6] 'Notes on the Correlation of the Cretaceous Rocks of the S.E. and W. of England,' *Geol. Mag.*, 1866, p. 15.

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Ammonitoceras] as being near the base of the Folkestone Sands and at about the same horizon as the Bargate Stone. The ammonite-fauna of the Bargate Stone, including true *Parahoplites* of the *nutfieldensis*-group, fully confirms Meyer's correlation, and the Folkestone Sands (beds I–III of Price) may thus correspond to the uppermost Aptian as correlated by Prof. Gregory,[1] or to the Lower Albian as indicated in the writer's table; or, what is more probable, with their nodule-beds above and below and possible non-sequences in between, the Folkestone Sands may represent the vestiges of a complicated succession of geological events that took place between the deposition of the *nutfieldensis*-beds from Kent to Wiltshire on the one hand and the existence of the *regularis*-fauna of Bedfordshire on the other. No ammonites seem to be known from the Sandgate Beds apart from the fragment recorded by Dr. Kitchin[2]; but in the Kentish Rag Beds of Hythe there are already Lower Aptian ammonites, including *Parahoplitoides*, *Dufrenoyia*,[3] *Cheloniceras* and '*Ancycloceras*.'

A provisional table of the ammonite zones of the Aptian may here be inserted. It is based on the attempts at correlation published by the writer[4] on previous occasions; but the '*furcatus*-zone,' formerly adopted with considerable doubt from French authors, notably Kilian[5] and Jacob,[6] has been omitted since the identification of *A. furcatus* Sowerby with the Lower Gargasian *Dufrenoyia dufrenoyi* (d'Orbigny) is obviously wrong. Jukes-Browne's term 'Vectian,' like his 'Selbornian,' is unnecessary.

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[1] 'On a Collection of Fossils from the Lower Greensand of Great Chart, in Kent,' *Geol. Mag.*, 1895, p. 103.

[2] In Lamplugh and Kitchin, 'On the Mesozoic Rocks in some of the Coal Explor. in Kent' (*Mem. Geol. Surv.*), 1911, p. 144.

[3] The genus *Dufrenoyia* Burckhardt, quoted by Kilian in 1915 ('La Faune de l'Aptien Infér. d. Environs de Montélimar,' Contr. à l'Étude d. Faunes Paléocrét. du S.E. de la France. I. *Mém. Carte Géol. France*, pp. 34, 35, 37; spelt '*Dufrenoya*' on pp. 178, 196, 198, 199, 203, 205, 207), has priority before *Stenhoplites* Spath ('On Cret. Ammonoidea from Angola,' *Trans. Roy. Soc. Edinb.*, vol. liii, pt. i, No. 6, 1922, p. 110); but according to kind information by Prof. Kilian, the name *Dufrenoyia* has not been published by Burckhardt. It may be advisable to retain the genus *Stenhoplites* for *A. furcatus* Sowerby, quite distinct from *D. dufrenoyi* (d'Orbigny) and of pre-*deshayesi* age. The genus *Hoplitides* v. Koenen, used by Franke ('Die Entfaltung d. Hopliten i. d. Unt. Kreide Norddeutschl.,' *Jahrb. k. preuss. geol. Landesanst.*, vol. xxxix, Teil I, Heft 3 (1918), 1920, pp. 491–3) for the group of '*Parahoplites*' *deshayesi* (Leymerie) has been restricted by Sayn ('Les Ammon. pyrit. d. Marnes Valangin. d. S.E. de la France,' *Mém. Soc. Géol. France, Pal.*, vol. xv, fasc. 2, No. 23, 1907, p. 64) to a division of *Leopoldia* occurring in the Valanginian Bed D2 at Speeton.

[4] *See* 'On Cret. Cephalopoda from Zululand,' *Ann. South Afr. Mus.*, vol. xii, pt. vii, No. 16, 1921, p. 311.

[5] 'La Faune de l'Aptien Infér. d. Environs de Montélimar,' Contr. à l'Étude d. Faunes Paléocrét. du S.E. de la France. I. *Mém. Carte Géol. France*, 1915, table to p. 114.

[6] 'Études Paléont. et Strat. sur la Partie Moy. des Terr. Crét.,' etc., *Trav. Lab. Géol. Univers. Grenoble*, vol. viii, 1908, p. 587.

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Ammonite Zones of the Aptian.

	Zones.	Subzones.	
Upper Aptian (Gargasian)	*subnodosocostatum*-zone (Parahoplitan)	aschiltaensis	Folkestone Sands? I. o. W. Sandrock Ser.
		nutfieldensis	Nutfield; Seend; Pulborough; Shanklin; Bargate Stone.
	martini-zone (Tropæuman)	tovilense	Maidstone
		bowerbanki	I.o.Wight, Ferrug. Sands
		hillsi	Hythe Rag; Upware
Lower Aptian (Bedoulian)	*deshayesi*-zone (Parahoplitoidan)	consobrinoides	I.o.Wight Crackers
		hambrovi	
		weissi	Atherfield Clay
		bodei	Perna Bed; Hunstanton Carstone; Speeton, B, top
	(Parancyloceratan)	bidentatus	Speeton, B., top
		rude	
		sparsicosta	

It is inadvisable to use terms like ' Sandgate Beds ' or 'Atherfield Clay ' for wider correlations; for even in such closely neighbouring localities as Dover, Hythe, and Brabourne the sandy, glauconitic, or clayey beds respectively do not belong to the same palæontological horizons.

Much work, of course, remains to be done on the Lower Greensand faunas. Hitherto the tendency has been to rely too much on the relative position of beds to relegate them to some formation intermediate between the over- and under-lying strata, sometimes in contradiction to fossil-evidence and with the sole desire of making the sequence complete. The ' Punfield Beds,' for example, styled Neocomian by Price,[1] were promptly taken by Kayser[2] to cover the two enormously long periods of the Valanginian and Hauterivian, and in his table are followed by the ' Atherfield Beds,' according to this author of Barremian age, and said to contain *Simbirskites decheni*. In reality none of these formations are represented in the marine Lower Cretaceous of the South of England and even the lowest Aptian is missing. The only ammonite of the Ferruginous Sands in the Punfield Series is a *Parahoplitoides*, transitional to *Dufrenoyia*, and probably younger, not older, than the *Parahoplitoides* of the Atherfield Clay, itself well above the base of the Aptian.

[1] ' The Gault,' 1879, p. 8.

[2] ' Lehrb. d. Geol.,' 3. Aufl., II. Theil. Geol. Formationskunde, 1908, table on p. 483.

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Again, Bed B of the Speeton Clay, the so-called *brunsvicensis*-zone, has *Simbirskites* of the group of *S. discofalcatus* (Lahusen) and *S. carinatus* (v. Koenen) at the base, and Aptian *Parahoplitoides* of the *bodei*-subzone (horizon of the base of the Hunstanton Carstone) at the top. Not a single typical Barremian ammonite has been found in the intermediate beds, though Barremian *Acrioceras* of the group of *A. tabarellii* (Astier) and *A. silesiacum* (Uhlig), here recorded for the first time, occur in the Snettisham Clay. Even in Germany the '*Crioceras*' of the beds between the Hauterivian below and the Aptian above show merely resemblance to, but not identity with, the forms of the typical Barremian, and the less complete succession at Speeton probably includes only part of the Barremian formation. The gap between the Aptian and Albian beds, however, at Speeton is far greater than that between the Lower Albian *regularis*-horizon of Leighton Buzzard and the Upper Aptian *nutfieldensis*-subzone of Surrey, Sussex, Kent, Wiltshire, and the Isle of Wight.

The great confusion existing at the present day in correlations of the Albian has been due largely to the reference to the 'Gault' of beds characterized by faunas of various ages; for instance, the *Parahoplites*-faunas of *nutfieldensis*-age in Mangyschlak and the Caucasus, the Upper Aptian beds of the Luitere Zug[1] with *Diadochoceras subnodosocostatum* (Sinzow), the Aptian faunas of North Germany, or the Lower Horsetown Beds of California, etc. It is to be hoped that the forthcoming description by the writer of the ammonites of the English Gault may help to clear up any doubts remaining about the exact horizons represented in the type-succession; and may cause to disappear from our fossil lists of the Gault such species as the Cenomanian *Protacanthoceras triserialis* (J. de C. Sow.), the Aptian '*Ammonites*' *bicurvatus* Michelin and *Parahoplitoides deshayesi* (Leymerie), the Valanginian '*A.*' *carteroni* d'Orbigny, and the Lower Liassic *Polymorphites parvus* (J. de C. Sowerby).

[1] Jacob & Tobler. 'Gault de la Vallée de la Engelberger Aa,' *Mém. Soc. Pal. Suisse*, vol. xxxiii, 1906, pp. 1–26, pls. i, ii.

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FOR

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